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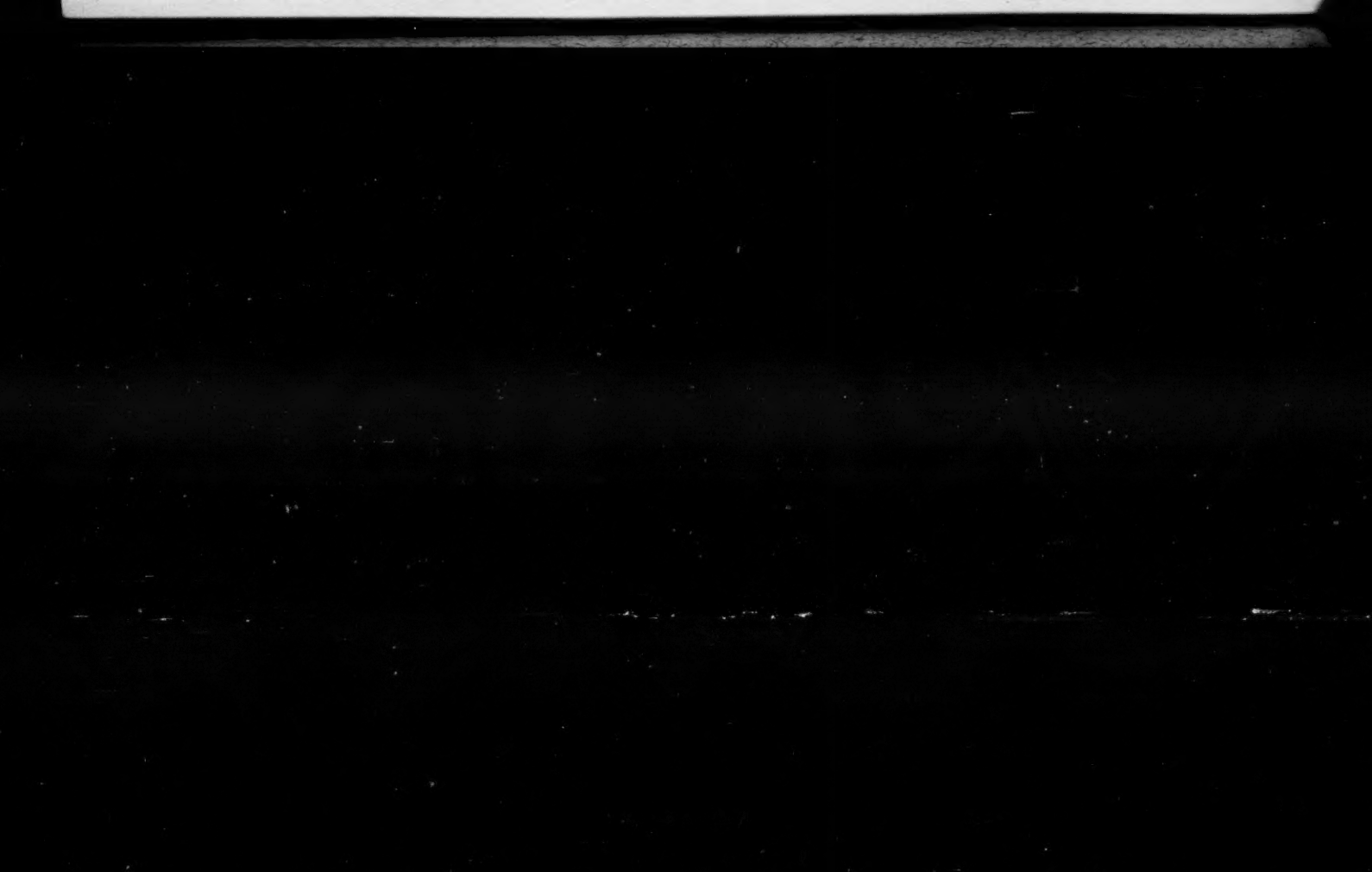

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THE ANIMAL HUSBANDRY CURRICULUM—ITS DEVELOPMENT AND OBJECTIVES[1]

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Davis

TEACHING animal husbandry is a challenge to the intellect, requiring mental capacity and critical judgment from those of us engaged in it. We accept such a responsibility and dedicate ourselves to the task.

Men differ in their concepts of university teaching. Benjamin Ide Wheeler once said, "A man who thinks he can govern his life by pure science is likely to be very wearisome to his neighbors and cumbersome to himself. The greatest education is the giving of life. Life is begotten of life, passes not from book to subject, but from the life of the Master to the life of the pupil." Herbert Spencer, however, stated, "A knowledge of the sciences is always most useful in life and therefore most worthwhile. Science opens up realms of poetry where to the unscientific all is blank." Robert A. Millikan said recently, "The job of civilized man is not to suppress the growth of knowledge, but rather to express his intelligence, his own growth of knowledge, to stop the depredations of the Dillingers and the Hitlers by eliminating them is necessary or by other means if he can find such, and at the same time to win as large a fraction of mankind as possible to the free choice of the good way instead of the evil way."

All three points of view are significant to the teaching profession because they deal with science, art, and man's position in the field of human relations.

In the beginning, animal husbandmen were forced to lean heavily on such basic sciences as zoology, chemistry, physics, mathematics, and botany. Pioneers had little to guide them in the new venture of teaching animal husbandry. *Feeds and Feeding* by W. A. Henry had not been published. Such important fields as genetics, nutrition, and physiology of the domestic animals were in their infancy.

Administrators had to depend upon personnel who had been trained in the sciences and humanities but had no farm background to teach animal husbandry, agronomy, horticulture, and other agricultural sub-

[1] From a talk presented at the meetings of the American Society of Animal Production held in Chicago, November 24th and 25th, 1949.
[2] Deceased.

jects. Early workers in the field of agriculture were basically trained, though they did not have the proper tools to apply their knowledge. The Federal Government, through the passage of the Morrill Act and through cooperation with the state institutions, had made the machinery available though there was yet little information as to how it could be successfully operated. The situation was a challenge to those who accepted the responsibility.

Under the guidance of a strong group of men with the spirit, the substance, and the will to do, the early foundation and philosophy of the field of scientific agriculture was determined. Included in this list of strong personalities were W. A. Henry, E. Davenport, H. P. Armsby, and others. They were scholarly, far-sighted individuals. In the years to come, H. L. Russell was a pillar of strength, always realizing that progress in this new field would be largely determined by advances in the basic sciences.

In the early part of the first decade after 1900, most students in animal husbandry spent considerable time in the academic halls of the state universities and utilized only such time as seemed essential in the technical phases of animal husbandry. While emphasis was placed on students of college grade, there were many young farm boys who lacked either the time or the required high school training, yet who needed information on livestock improvement through feeding, breeding, management, and marketing. To meet this need, many state universities developed short courses that could be attended during the winter months. Students who attended such courses returned to the farms and put into practice what they had learned during the part of the year when farm work was at low ebb.

So far the farm youth were being served, but what of the adult who owned or rented the land upon which he produced meat, milk, leather, and other useful products? The need for training at home resulted in the passage of the Smith-Lever Act in 1914, an act which developed the Agricultural Extension Service and the 4-H Club programs. There was a great demand for technically trained men to fill important positions in the rapidly growing colleges of agriculture. The demand exceeded the supply. Because faculty members were selected who would attract livestock producers, personality rather than training was often the yardstick used. Such men as E. Davenport and H. L. Russell remained steadfast in their knowledge that science would solve the most difficult problems. Agricultural chemistry became an important part of the more advanced curricula as a basis for applied nutrition and feeds and feeding. Later genetics was recognized as a basis for applied animal breeding.

Physiology had already been accepted as an important subject for animal husbandry students.

In the meantime, technical animal husbandry expanded rapidly. Valuable text books were published, some important ones like Henry's *Feeds and Feeding*. Administrative officers approved a vast array of technical animal husbandry courses in an effort to provide factual information for immediate use. To "pass" some courses required little thought or effort on the part of the farm-grown students—the "how" was presented, but not always the "why."

Agricultural experiment stations conducted many feeding experiments with livestock. Reports and bulletins published by them served to answer many questions and were useful in improving animal husbandry teaching.

While education needs of adults and college students were recognized, nothing was being done for the high school student. To fill this gap, the Smith-Hughes Act was passed by Congress early in 1917. This resulted in increased demand for agricultural college graduates at the bachelor level. With agriculture as a subject taught in high school, the need for short courses became less, with the result that at many colleges they have been abandoned.

Finally, in 1935, the Bankhead-Jones Act was passed providing additional federal funds for research and for instructional purposes. This further resulted in strengthening teaching in most land-grant colleges.

The demand from producers to solve old and new problems focused the attention of administrators upon the need for better-trained teachers and research workers in animal husbandry. It is a fact that improvement in farm animals had progressed. While courses in livestock judging were an important factor in teaching college students to distinguish good animals from bad, there were other important problems that needed solution. The sciences of mathematics, physics, chemistry, zoology, and such applied sciences as genetics, nutrition, and physiology were recognized as the means of attempting to find the answers.

To discuss animal husbandry teaching since the turn of the century, it appeared necessary to locate certain land marks as a basis for proceeding. Michigan State College had developed a teaching program for agriculture before the Morrill Act was passed in 1862. Many early graduates from Michigan became outstanding men in leading universities of the Nation.

What progress has been made in animal husbandry curricula in the past half century? Three are discussed here—Michigan State College, 1900–1901; Missouri, 1927–28; and California, 1950–51. They are

summarized in table 1 together with a proposed curriculum, which will be discussed later.

These curricula are not identical, but they are essentially similar. Basic sciences are stressed in each. Applied sciences such as genetics and nutrition, in their infancy in 1900, were not mentioned. English

TABLE 1. CURRICULA SUMMARY[1]

	Michigan State College 1900–01	University of Missouri 1927–28	University of California 1950–51	Proposed Curriculum (1950 Minimum requirement)
Agriculture	30.9	25.0	19.0[2]	30.0[2]
Mathematics	11.7			
Chemistry	8.2	16.0	18.0	13.0 (incl. biochemistry)
Physics	5.4	5.0	6.0	5.0
Botany	9.8	5.0	4.0	4.0
Zoology	2.6	5.0	10.0	5.0
Economics	1.7	5.0	6.0	6.0
Anatomy and Physiology	3.2		5.0	4.0
English	16.2	6.0	3.0	6.0
History	2.6		5.0	5.0
Drawing	2.6			
Civil Engineering	1.6			
Veterinary Science	1.1	5.0	3.0	3.0
Military Science	4.8	6.0	8.0	8.0
Thesis	2.6			
Citizenship		4.0		
Bacteriology		3.0	4.0	3.0
Geology		3.0	3.0	3.0
Genetics			4.0	4.0
Free Electives	19.0	36.0	26.0	25.0[4]
TOTAL	124.0	124.0	124.0	124.0

[1] Credits reduced to semester hours or units.
[2] Includes animal husbandry 21 units, agronomy 6 units, agricultural engineering 3 units.
[3] Mathematics through trigonometry (In California this is usually completed in high school but will necessarily vary in different areas).
[4] At least 5 units to be selected from the humanities.

and mathematics were emphasized in the early curricula. The California curriculum includes basic as well as applied sciences.

In the early Michigan State curriculum, there existed a balance between the sciences, the humanities, and livestock production. In the Missouri curriculum of 1927–28, the total units required in the sciences and mathematics are fewer than in the other two curricula presented. The technical phases of agriculture are stressed, but opportunity is

afforded for the student to select courses from a large number of electives. This may or may not be advisable depending somewhat upon the student and his adviser. The California curriculum emphasizes science and the applied sciences, with opportunity for production and other agricultural courses, but allows only a limited selection of courses in the humanities.

If college training in animal husbandry before the turn of the century produced strong characters and leaders in the field, it is only logical that the curricula then and now should be somewhat similar. Because the volume of scientific and technical knowledge has increased many-fold during the past fifty years, information presented to the student needs to be condensed. It is probable that students can retain more now, and also that high school training is better than it was in 1900.

What are the objectives of animal husbandry teachers and research workers? Through our knowledge of the applied sciences and of improved management practices, concerted effort should be made to maintain the fertility of the soil we are privileged to use through judicious use of livestock in our agricultural practices. Further, "a balance should be found between livestock and feed production with proper evaluation of a better forage supply and more efficient livestock" (from a report of a committee of Oregon State College).

We must see that animal husbandry students are trained by teachers with vision and understanding in chemistry, mathematics, physics, zoology, botany, and geology. They should have a thorough understanding of the elements of genetics, physiology, and nutrition. It is important too that they learn the application of these sciences to the problems of animal production. They need to know how to select their animals—the excellent, the good, the mediocre, and the poor. They cannot secure this information from a textbook. It is imperative that they know how to feed animals of the various ages and species, how to mate animals for best results, and how to manage an animal husbandry enterprise. They should learn something of economics because it threads its way through the whole process of production. If they are to be good farmers or teachers or research workers, they must have a knowledge of agronomy, of power machinery, of drainage in some areas, and of irrigation in others. Then, too, they must be good citizens and must get along with others. A knowledge of the humanities is therefore necessary. Fundamentally, the basic training in all parts of the Nation should be similar, but the application may differ widely depending upon whether the student attends an eastern, southern, middle western, or a western institution.

Table 2 contains a proposed curriculum indicating minimum requirements in science, agriculture (including animal husbandry), and the humanities and is suggested to make it possible for students to transfer

TABLE 2. AN ANIMAL HUSBANDRY CURRICULUM

Course	Minimum Units
Lower Division—Freshman and Sophomore years:	
Inorganic chemistry	5
Organic chemistry	3
Physics	5
Zoology	5
Economics	6
Geology	3
Bacteriology	3
Botany	4
English	6
Animal Husbandry	4
Military Science and Physical Education	8
Electives	7
TOTAL	62[1]
Upper Division—Junior and Senior years:	
Genetics	4
Physiology	4
Biochemistry	5
Feeds and Feeding	3
Animal Breeding	2
Animal Husbandry (Production and other courses, including 1 unit in experimental methods)	12
Agronomy	3
Veterinary Science	3
Agricultural Engineering	3
History	5
Electives	18
TOTAL	62

Electives:

25 units to be taken from the following or other subjects (at least 5 units to be selected from the humanities)

Animal Husbandry	Chemistry
Agronomy	Physics
Agricultural Engineering	English and Languages
Agricultural Economics	History
Dairy Production or Manufacturing	Mathematics
Irrigation or Drainage	Philosophy
Veterinary Science	
Soils	

[1] In California mathematics through trigonometry usually is completed in High School. This will, of course, vary in other areas.

more easily from one university to another. If this or a similar curriculum were accepted by most institutions, it would surely be an advantage to a student with a baccalaureate degree from one school in transferring and matriculating in the graduate division of another university.

Such a curriculum should result in our students becoming educated men and women capable of leading a fuller life. It should aid in helping the individual make a living for his family. The graduate should have a better understanding of citizenship and an appreciation of his personal responsibility to the community in which he lives. Furthermore, such a course of study should result in the individual's having a better understanding of life processes, of himself, of his fellowmen, and of the animals with which he works.

But what of practical experience? Where will a student acquire it if he does not have it? To those in the central part of the Nation, this may be an easy problem, but it challenges the best efforts of those who teach in areas where the urban population far exceeds the rural. To the farm-reared, it is no serious problem; but to the city boy who makes up his mind to live in the country, it is often the primary problem. Cornell and other institutions are doing something about it. The University of California with a grant of $250,000 is making a serious beginning in the direction of helping those who deserve and want to gain practical farm and animal husbandry training.

Since the problems of the producer are in many ways as complex as those of the experiment station worker, only a single curriculum is needed. During the senior year, the choice of electives might vary, depending upon the direction the student expects to go. For the man going into research, additional mathematics and a foreign language in undergraduate years would be desirable if other requirements have been satisfied.

Before concluding, attention should be called to the new junior colleges sometimes referred to as community or city colleges. In 1948–49, 465,815 students were registered in 648 community colleges. In many sections of the nation a large percentage of professional and other students enter our universities from these institutions. Such students may complete their science, English, mathematics, economics, and other requirements before becoming animal husbandry majors in the colleges of agriculture. This need not change the requirements of the men, but it may necessitate some changes in the sequence in which courses are taken. Except in isolated cases, junior colleges are not yet qualified to teach advanced technical or professional courses.

It is not my purpose to suggest in detail what courses should be taught to the animal husbandry student. However, he should receive sufficient training in the basic sciences, economics, plant life, nutrition, genetics, and physiology, and in production to qualify him to take an undergraduate course in experimentation, so that he will have the proper tools to work with when he is granted his degree. It does not matter whether he becomes a farmer or an industrialist, takes up vocational teaching or extension work, or accepts a position in an agricultural college and experiment station—a knowledge of experimental methods and procedure is becoming more and more important. We are continually looking for the truth, rediscovering the old and finding the new. The young graduate should have the imagination, the will to do, and the working tools to add his link in the chain of new knowledge. Whether it be in someone's back yard, basement, barnyard, cornfield, or in an experiment station matters little.

The young college student who is honest will not shirk or complain but rather, in the words of W. J. Cameron, "Squaring his shoulders and lifting his chin, he will cast his lot where American youth has always cast it—on the side of those who give before they take, the creators and builders, contributors of energy, talent, and service, whose reward is not something they take out of America, but sharing the life they feel by what they put in."

ENVIRONMENTAL SOURCES OF VARIATION IN THE GESTATION LENGTH OF THE HORSE

C. E. Howell and W. C. Rollins
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SEVERAL studies, some of which involve extensive amounts of data, have shown that season of breeding or foaling is the most important single source of variation in the gestation lengths of mares: (Uppenborn, 1933; Mauch, 1937; Berliner, 1942; Britton and Howell, 1943). These studies present no direct experimental evidence for the cause of this seasonal variation. This present study in addition to investigating the relative importance of various environmental sources of variation is concerned with the question of to what extent, if at all, the above mentioned seasonal variation in the gestation lengths of mares is a reflection of a seasonal variation in the level of nutrition of mares.

Material Studied

The records analyzed were taken at the time the University of California operated the W. K. Kellogg Arabian Horse Ranch at Pomona, California and cover the period from 1932 to 1943. There are 186 recorded gestation lengths associated with single live births resulting from the matings of 12 stallions with 36 mares.

As regards management and feeding, the mares can be divided into two groups. One group of mares was kept on native pasture almost the year around and can be considered as having received a maintenance ration. The pasture consisted mainly of wild oat grass, some bur clover and a little alfilaria.

During the months of March, April and May, the grass was green and grew in abundance. The mares would take on a little flesh during this period. The grass furnished a little more than a maintenance diet. During the months of July, August and September, the grass would become very dry and lack somewhat in palatability. The mares would lose weight slightly, thus indicating that they were on a slightly submaintenance diet.

During the winter months these mares had free access to an open shelter where they could receive oat hay *ad libitum*. The area over which the animals pastured was rolling hills varying from 200 to 400 feet in

[1] Davis, California.

altitude. The four pasture fields varied in size from 40 to 100 acres. Consequently these mares had an excellent opportunity to take adequate exercise. Since these mares weighed from 970 to 1,020 pounds, it is estimated that they consumed from 7 to 8 pounds of total digestible nutrients per day, in order to maintain their body weight.

The second group of mares, considered to be well fed, were either stabled or confined in small corrals adjacent to the barn and were fed grain and hay with a limited amount of pasture in the winter and

TABLE 1. AVERAGE GESTATION LENGTH ACCORDING TO MONTH AND SEASON OF BREEDING

Month	Number	Monthly Average	Seasonal Average
December	10	335.8	
January	16	338.3	338.1
February	24	338.9	
March	27	341.6	
April	23	343.8	342.2
May	16	340.8	
June	12	333.4	
July	11	331.3	330.9
August	6	325.0	
September	9	330.0	
October	23	328.0	328.8
November	9	329.7	
Total	186		336.4

spring. These mares were in an exhibition show every Sunday afternoon. In order to keep them properly trained for their exhibition they were put through their exercise for two or three hours at least four days of every week. These animals were kept in show condition all the time. Their average weight was about 1,050 pounds. The ration fed furnished each animal with 10 to 11 pounds of total digestible nutrients per day. The amount of energy expended by this group of mares corresponds to what is ordinarily called light work.

Analysis

Year, Season and Month

Average gestation lengths for month and season of breeding are presented in table 1. Analysis of variance indicates that monthly varia-

TABLE 2. ANALYSIS OF VARIANCE OF GESTATION LENGTH FOR MONTH AND SEASON OF BREEDING

Source of Variation	Degrees of Freedom	Mean Square
Seasons	3	1,865.71**
Months within Seasons	8	61.64
Within Months	174	62.43

**P<0.01.

tion is unimportant after eliminating the highly significant seasonal variation (table 2). The major seasonal difference is between the combined winter and spring season (which is the rainy season) and the combined summer and fall or dry season. The average for the rainy season is 10.8 days longer than for the dry season.

Since the gestation length for horses is about 11 months and mares are often rebred on the foal heat the question may arise: To what extent does the observed seasonal difference in gestation length reflect the individuality of mares that may have been repeatedly bred in the same season? To check on this point, the average seasonal difference within mares was calculated for all those mares which produced offspring resulting from breedings in both the dry and rainy seasons. This average difference is 9.3 days (table 3). It appears therefore, that the seasonal difference indicated in these data is not due to the tendency of some of the mares to be repeatedly bred in the same season.

Yearly variation was tested for the three year period December 1938 through November 1941. This period was chosen for such a test because the progeny of the three stallions that were the most prolific (that is, as far as these data are concerned) were quite uniformly distributed

TABLE 3. A COMPARISON OF THE DIFFERENCE BETWEEN SEASONAL AVERAGES OF GESTATION LENGTH WITHIN MARES AND DISREGARDING MARE DIFFERENCES

	Number of Mares	Number of Offspring from Breeding in:		Seasonal Difference between average gestation lengths
		Rainy Season	Dry Season	
Within Mares	22	56	54	9.3
Disregarding mare differences	36	116	70	10.8

TABLE 4. ANALYSIS OF VARIANCE OF GESTATION LENGTH FOR YEAR AND SEASON OF BREEDING (METHOD OF EXPECTED SUBCLASS NUMBERS)

Source of Variation	Degrees of Freedom	Mean Square
Years	2	53.27
Seasons	3	954.09**
Years x seasons	6	38.67
Within subclasses	67	53.49

**P<0.01.

over seasons and years within this period. The analysis of variance (table 4) indicates no significant year or year X season effects.

Sex, Foaling Sequence and Season

These data include gestation lengths for first through 13th foalings. In the analysis of variance of the joint effects of sex, foaling sequence and season upon gestation length (table 5) the order of foaling was divided into two classes namely, gestation lengths resulting from first through fourth foalings and those from fifth foalings and up. This arbitary division was dictated by the number of data available and is only useful for testing for a rough linear trend due to age of mare.

Table 5 indicates that of the various main effects and first and second order interactions only that of season is statistically significant. The analysis also yields an estimate that gestation lengths resulting from later foalings are two days longer than those from early foalings. This difference while not statistically significant is similar to results found by Mauch (1937).

TABLE 5. ANALYSIS OF VARIANCE OF GESTATION LENGTH FOR SEASON OF BREEDING, SEX AND FOALING SEQUENCE (METHOD OF EXPECTED SUBCLASS NUMBERS)

Source of Variation	Degrees of Freedom	Mean Square
Seasons	3	2,018.09**
Sex	1	15.73
Foaling sequence	1	169.43
Season x sex	3	14.02
Season x F.S.	3	121.21
Sex x F.S.	1	11.90
Season x sex x F.S.	3	88.35
Within subclasses	170	62.02

**P<0.01.

Nutrition and Season

As previously indicated in the description of the experimental material, eight of the 36 mares were kept at the stables on a high level of nutrition. They also had limited access to pasture. In the spring of 1941 these mares constituting the "well fed" group were turned out to pasture permanently and thereafter were managed and fed as previously described for the group receiving a "maintenance ration." Prior to the spring of 1941, the eight mares constituting the "well fed" group produced 23 offspring with an average gestation length of 331.3 days.

TABLE 6. AVERAGE OBSERVED GESTATION LENGTHS ACCORDING TO LEVEL OF NUTRITION OF THE MARE AND SEASON OF BREEDING

Season of Breeding		Level of Nutrition		Total
		Well fed	Maintenance Ration	
Rainy Season (December through May)	Number	11	105	116
	Average Gestation Length	335.6	340.9	340.4
Dry Season (June through November)	Number	12	58	70
	Average Gestation Length	327.3	330.1	329.6
Total	Number	23	163	186
	Average Gestation Length	331.3	337.1	336.4

Subsequent to the above period these same eight mares produced nine offspring with an average gestation length of 337.9 days.

Table 6 summarizes the data used in jointly testing the effect of season of breeding and level of nutrition upon gestation length. Under the classification "Level of Nutrition", "well fed" refers to the mares kept about the stables during gestation while "maintenance ration" refers to mares kept on pasture during gestation.

The method of "fitted constants" was used in analyzing the variance of gestation lengths with respect to these causes of variation. This method of analysis provides a valid test of interactions between main effects and in the absence of such interactions yields unbiased and efficient estimates of the differences between the main classes (Yates 1934). In this case, a test for interaction between season and level of

nutrition yielded a mean square less than the error variance. This indicates that seasonal variation is independent of level of nutrition. The analysis of variance is set forth in table 7. An unbiased estimate of seasonal effect with level of nutrition held constant indicated gestation lengths resulting from breedings in the season December through May to be 10.4 days longer than those resulting from breedings in the season June through November. For level of nutrition with season held constant an unbiased estimate of the gestation length for mares "well fed" was 4 days shorter than for mares on a "maintenance ration".

TABLE 7. ANALYSIS OF VARIANCE OF GESTATION LENGTHS FOR SEASON OF BREEDING AND LEVEL OF NUTRITION (METHOD OF "FITTED CONSTANTS")

Source of Variation	Degrees of Freedom	Mean Square	Expected Value of Mean Square	Variance Components	Percent of Total Variance
Season	1	4,710.09**	86.20 S + W	53.91	43.6
Level of Nutrition	1	322.79*	39.80 N + W	6.53	5.3
Within Subclasses	183	63.24	W	63.24	51.1

**P<0.01.
* P<0.05.

Discussion

It is a well established fact that season of breeding is an important source of variation in the gestation lengths of mares. Our study along with those of Uppenborn (1933) and Mauch (1937) indicate that of all the causes of variation investigated it is by far the most important. Berliner (1942) also reports seasonal variation of a similar magnitude to those reported in the studies cited above. Reducing the findings of all the above to a lowest common denominator, so to speak, it turns out that gestation lengths resulting from spring breedings (March through May) are on the average one to two weeks longer than those resulting from summer and fall breedings (June through November). These studies in total deal with horses reared in a widely distributed area in the Northern Hemisphere, namely:

Authors	Location of Studs Studied
Howell and Rollins	Southern California
Berliner	Mississippi
Uppenborn	Germany
Mauch	Rumania

In each of these locations the pasture seasons overlap to a large extent and in any event all fall somewhere within an overall period of March to October.

Uppenborn, Mauch and Berliner offer no experimental evidence as to the cause of the above mentioned seasonal variation. Uppenborn (1933) suggests that this seasonal effect is tied up with weather, maintenance and nutrition. Mauch (1937) attributes the seasonal effect to the influence of the pasture season.

In our study we have compared a "well fed" group of mares whose year around level of nutrition was little dependent upon the condition of pasture with a group on "maintenance ration" whose nutrition was mainly dependent upon pasture. We found that seasonal variation was the same for both groups. This implies that there is some important factor associated with season other than or in addition to the condition of the pasture that is operating to produce the observed seasonal variation. Seasonal variation in the length of daylight acting upon the endocrine system of the mare suggests itself as a possible cause. The effect of this phenomenon on the reproductive functions of sheep is well known. Furthermore, Berliner (1942) reports that seasonal factors affecting the growth of pastures have a definite effect on the estrous periods of both mares and jennets.

Our study indicates that level of nutrition of the mare has a significant effect upon gestation length independent of seasonal variation. "Well fed" mares had gestation lengths that averaged four days shorter than for mares on a "maintenance ration." Both groups of mares were receiving exercise in an amount consonant with good condition. This result is similar to those reported by Uppenborn (1933). First, in studying the effect of the war years (World War I) he found that on the average gestation lengths for the war years 1914–1919 were about five days longer than those for the periods immediately preceding and following the war namely 1910–1914 and 1919–1928. He attributed this increase in gestation length during the war years to a lower plane of nutrition resulting from a decrease in quantity and quality of supplemental feed and from the deterioration of pastures due to overgrazing and inadequate fertilization. Secondly, he mentions the results of Von Oettingen's study of the records of certain German studs for the periods 1868–1877 and 1903–1907. He found that gestation lengths for the latter period 1903–1907 averaged about five days shorter than those for the former period 1868–1877. Von Oettingen attributed this decrease to the improvement in pastures and to better feeding of the mares.

The age of the mare may have a slight effect upon the length of time she carries her foetus. Our results indicate this but they are not statisti-

cally significant. Mauch's (1937) results also suggest a slight tendency for gestation length to increase with the age of the mare.

Uppenborn (1933) and Mauch (1937) both report a highly significant but small difference in gestation lengths due to the sex of the foetus. In each case males are carried longer than females. The former reports an average sex difference of $1.6 \pm .2$ days and the latter $1.7 \pm .5$ days. That our results indicated no significant sex effect is probably due to the relatively few data analyzed.

Summary

An analysis of the environmental sources of variation in the length of the gestation period of Arabian mares has been made.

Season of breeding is the most important source of variation in gestation length. It accounts for 44 percent of the total variance. Pregnancies resulting from breedings during the period December through May on the average were 10.4 days longer than those resulting from breedings during the period June through November.

Level of nutrition of the mare accounted for five percent of the total variance. Pregnancies of "well fed" mares averaged 4 days shorter than those for mares on a "maintenance ration."

Seasonal variation in gestation length was found to be independent of the level of nutrition of the mare, thus implying that there is some important factor associated with season other than or in addition to level of nutrition of the mare that is operating to produce the observed seasonal variation. The Authors briefly discuss the possibility that this factor may be the seasonal variation in the length of daylight.

The influence of the stallion and other sources of genetic variation in the gestation length of the horse is discussed by the Authors in a companion paper to this (Rollins and Howell, 1951).

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GENETIC SOURCES OF VARIATION IN THE GESTATION LENGTH OF THE HORSE[1]

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INVESTIGATIONS of the influence of the sire on the length of gestation of its offspring have been more numerous for cattle than for horses. For cattle the following studies report an influence of the sire: (Knott, 1932; Düring, 1937; Rife *et al.*, 1943; Rife, 1948; Alexander, 1950; Jafar *et al.*, 1950). Terrill and Hazel (1947) report an important influence of the ram on gestation length in sheep. For the horse, Uppenborn (1933) reports an influence of the stallion while Mauch (1937) found no such influence. Both Uppenborn and Mauch report a decided influence of the stallion on the gestation lengths associated with the pregnancies of the stallion's daughters.

In the present study of the horse, a partitioning of the variance of gestation lengths into genetic and non-genetic components affords among other things a quantitative estimate of the influence of the stallion on the gestation length of the offspring.

Source of Data

The data analyzed are 186 recorded gestation lengths associated with single live births of purebred Arabian horses. These data covering the period 1932 to 1943 were collected by one of the authors, (C.E.H.) while he was associated with the Arabian stud at the Kellogg Ranch in Pomona, California. Howell and Rollins (1951) describe the management and breeding of the stocks involved.

Genetic Analysis

The data prior to genetic analysis were adjusted for the effects of season of breeding and level of nutrition of the mare (Howell and Rollins, 1951).

Using the principles formulated by Wright (1921, 1935), the phenotypic variances within and between several types of families were analyzed to afford estimates of genetic and non genetic components of phenotypic variance. The mating structure of the herd afforded data

[1] This work was supported by the Kellogg Fund for the application of genetics to farm mammals.
[2] Davis, California.

that could be grouped in the following types of families; paternal half sibs, maternal half sibs and full sibs.

Paternal Half Sib Estimate of Heritability

From the analysis of variance according to sires (table 1) the estimated intra class phenotypic correlation for paternal half sibs is $p=0.083$. An estimate of heritability (g^2) is given by $g^2=p/r$ (ignoring possible epistatic effects) where r is the genetic relationship of family members. For a random breeding unit $r=\frac{1}{4}$. In this herd there was some relationship between sire lines, so that the effective $r=\frac{r_1-r_2}{1-r_1}$ (Lush, 1945) where r_1 is the family relationship on the supposition

TABLE 1. ANALYSIS OF VARIANCE OF GESTATION LENGTHS ACCORDING TO SIRES

Source of Variation	Degrees of Freedom	Mean Square	Expected Value of Mean Square	Variance Components
Total	185	62.61		
Sires	11	132.57*	14.19 S+W	5.24
Within Sires	174	58.18	W	58.18

*P<0.05.

that the different families are unrelated, and r_2 is the average relationship between families. In this case r turns out to be 0.23 giving $g^2=0.36$.

Sex Linkage

For most of the quantitative characters in domestic animals that have been studied no significant effects of sex-linked genes have been found (Lerner, 1950; Lush, 1948). However, certain results found in the literature on gestation lengths in horses and cattle (to be discussed later) led us to consider the possible manifestation of such effects in these data.

On the supposition that all genes concerned have equal effects and equal frequencies, Lush (1948) works out the expected genetic relationship between parents and offspring for the case where the number of sex linked loci is not disproportionately large. From these values of r (sire to son)=0.487 and r (sire to daughter)=0.506 one obtains for the paternal half sib family, r (male half sibs)=0.237 and r (female half sibs)=0.256. The two values of r are approximately equal

TABLE 2. ANALYSIS OF VARIANCE OF GESTATION LENGTHS OF FEMALE OFFSPRING ACCORDING TO SIRES

Source of Variation	Degrees of Freedom	Mean Square	Expected Value of Mean Square	Variance Components
Total	98	73.72		
Sires	9	117.64	9.17 S+W	5.27
Within Sires	89	69.28	W	69.28

and hence the effect of sex linkage is negligible. However, as the proportion of sex linked loci increases, the discrepancy between the genetic correlations of male and female paternal half sibs increases, reaching limiting values of r (male half sibs)=0 and r (female half sibs)=0.5.

Within a paternal half sib family the expected genetic variance will be the same for male half sibs as for female half sibs irrespective of the proportion of sex linked loci to autosomal loci. Hence since S (the component of phenotypic variance due to sire differences)=r G, the extent to which S (for female half sibs) exceeds S (for male half sibs) will be an indication of the importance of sex linked genes in conditioning the trait under discussion.[3] By "importance" in this sense is meant the relative frequency of sex linked loci to autosomal loci.

In tables 2 and 3 estimates of S are presented for female and male paternal half sibs respectively. The estimated variance within sires (W) for females is 69.28 as contrasted with 48.01 for males. To test for a significant difference between these estimates both tails of the F distribution must be used since the theoretical value of these estimates is the same. Making the test we find $F=1.44$ and $F_{.05}=1.60$. Thus the difference between these within family variance estimates can reasonably be attributed to sampling error.

TABLE 3. ANALYSIS OF VARIANCE OF GESTATION LENGTHS OF MALE OFFSPRING ACCORDING TO SIRES

Source of Variation	Degrees of Freedom	Mean Square	Expected Value of Mean Square	Variance Components
Total	86	50.67		
Sires	11	68.79	6.66 S+W	3.12
Within Sires	75	48.01	W	48.01

[3] See table 4 for a partial glossary of symbols used.

Estimation of Components of Phenotypic Variance (Continued)

Estimates of intraclass correlations for maternal half sib and for full sib families were each significantly different from zero at the one percent level of probability. In grouping the data into these types of families, the fact that many mares were mated to several of the same stallions led to difficulties in evaluating maternal effects and genetic relationships between families. It was decided to work with pooled estimates of variance within families. Table 4 presents these estimates along with

TABLE 4. POOLED ESTIMATES OF VARIANCE WITHIN FAMILIES AND THEIR THEORETICAL COMPOSITION

Type of Family	Total Number Involved	Degrees of Freedom	Pooled Estimate of Within Family Variance	Theoretical Composition of Within Family Variance[1]
Paternal Half Sib	186	174	58.18	$\frac{3}{4}$ G+D+15/16 I+E+M
Maternal Half Sib	135	86	43.04	$\frac{3}{4}$ G+D+15/16 I+E
Full Sib	146	88	35.14	$\frac{1}{2}$ G+$\frac{3}{4}$ D+$\frac{3}{4}$ I+E

[1] Additive Genetic Variance (Obtained from Table 1 and Corrected to a Random Breeding Basis) G=22.74
Variance Due to Dominance Deviations from the Additive Scheme D= 8.84
Variance Due to Epistatic Deviations from the Additive Scheme I= 0.00
Variance Due to Permanent Maternal Effects M=15.14
Variance Due to Unanalyzed Residual Effects E=17.14

Phenotypic Variance G+D+I+M+E = 63.86

their theoretical composition. Using the value of G obtained from table 1 corrected to a random breeding basis and assuming I=O we can use the information in table 4 to obtain estimates of the remaining parameters. The estimates obtained lead to the following partitioning of the phenotypic variance:

Estimated percentage of variance due to:

Additive gene effects.....g^2=35.6
Dominance deviations from the additive scheme...d^2=13.8
Permanent maternal effects.....m^2=23.7
Unanalyzed residual effects.....e^2=26.9

Table 5 presents the relative importance of the investigated sources of variation in gestation length including season of breeding and level of nutrition of the mare.

Discussion

According to Uppenborn (1933) the stallion has some influence on the length of time that his offspring is carried by the mare. Such an influence of course would be exerted through the genotype of the foetus. He reached this conclusion by comparing the difference between the average gestation lengths of groups of paternal half sibs. Mauch (1937) concluded that his data exhibited no effect of the stallion. In comparing his conclusion with that of Uppenborn he states (The authors' translation from German): "Uppenborn went on the assumption that the stallions of a stud were used on essentially the same mares and therefore

TABLE 5. RELATIVE IMPORTANCE OF SOURCES OF VARIATION IN GESTATION LENGTHS

Source of Variance	Variance Components	Percent of Total Variance
Season of Breeding	53.91	43.4
Level of Nutrition of Mare	6.53	5.2
Level of Nutrition X Season of Breeding	0.00	0.0
Genotype of Foal		
Additive	22.74	18.3
Dominance Deviations	8.84	7.1
Permanent Maternal Traits	15.14	12.2
Residual	17.14	13.8
Total	124.30	100.0

the influence of the dam remained more or less constant for all stallions. The differences which show for the gestation period length of foals of each stallion are traced back to the influence of the sire. This method of calculation has this drawback, as was at all events the case in our material, that in each stud there are a large number of mares with which the stallion in question has not been bred . . . to disentangle the maternal from the paternal effect we compared the average gestation length of a particular stallion's foals with the average of all foals delivered from the mares mated to the stallion in question."

Since there is no mention or suggestion of assortative mating in either of the works cited it would seem that Mauch's criticism of Uppenborn is unwarranted. Furthermore, it would seem that Mauch's failure to recognize significant results in his data on this point was due to the method of statistical analysis employed, namely, comparing pairs of means with the standard error of their differences and employing no method of pooling the analyses of his various sets of data for a more

precise test of the effect in question. In table 6, page 37 of his paper Mauch presents in the form of means, standard error of means and number of offspring, the necessary data for a paternal half sib estimate of heritability. The data are from the breedings of 36 stallions distributed over five studs representing the following four breeds: Arab, Lipizzanser, Gidran and Nonius. An intra-stud analysis of variance of these data is presented in our table 6. The paternal half sib estimate of heritability from Mauch's data is 27 percent and is based on an intra-class correlation coefficient (derived from table 6) that is significantly different from zero at the one percent level of probability. That this estimate of heritability is lower than our estimate of 36 percent,

TABLE 6. POOLED[1] INTRA-STUD ANALYSIS OF VARIANCE OF GESTATION LENGTHS ACCORDING TO SIRES

(Mauch's Data)

Source of Variation	Degrees of Freedom	Mean Square	Expected Value of Mean Square	Variance Components
Total	1529	107.97		
Sires	31	413.28**	42.06 S+W	7.42
Within Sires	1498	101.65	W	101.65

** $P<0.01$.

[1] In pooling data from four different breeds the authors have, in part, been influenced by the degree of similarity in the historical background of the breeds in question (Frölich, 1926) and by the belief that there has been no intense artificial selection practiced with respect to the trait under consideration.

probably is a reflection of the fact that Mauch's data were not corrected for season of breeding which is an important source of variation in the gestation lengths of horses (Howell and Rollins, In Press).

To the authors' knowledge, the literature on horses contains no estimates of heritability. However, reported estimates of heritability of gestation length of cattle and sheep fall in the same range with these being reported for the horse. For Rambouillet sheep, Terrill and Hazel (1947) estimate heritability at 30 to 40 percent. Jafar *et al.* (1950) estimate heritability in Holstein Friesians at 32 percent. From the results presented in tables 1 and 3 of Düring's paper (1937) one obtains an estimate of 43 percent for Swedish Friesian cattle.

Our estimate of the proportion of the variance of gestation length due to permanent differences between mares is 24 percent. We were unable to partition this into genetic and non-genetic components. Both Uppenborn (1933) and Mauch (1937) report that a certain typical

gestation length is characteristic for the pregnancies of the daughters of a stallion. For such a group of foalings the dams would be paternal half sibs and under random mating the variance within such a group (W) would have the following theoretical composition:

$$(1)\quad W = 15/16\ G_o + D_o + I_o + \tfrac{3}{4}G_m + D_m + 15/16\ I_m + C + E$$

Where

For the Foal:

G_o = Additive genetic variance
D_o = Variance due to dominance deviations from the additive scheme
I_o = Variance due to epistatic deviations from the additive scheme

For the Mare:

G_m = Additive genetic variance
D_m = Variance due to dominance deviations from the additive scheme
I_m = Variance due to epistatic deviations from the additive scheme
C = Variance due to permanent non-genetic maternal effects
E = Variance due to factors peculiar to a particular foaling

In tables 7 and 8 of his paper, Mauch (1937) presents data on 476 foalings arranged in nine groups of the above type. These data yielded a pooled estimate of W=87. From the paternal half sib analysis of Mauch's data we obtain an estimate of

$$(2)\quad G_o + D_o + I_o + G_m + D_m + I_m + C + E = 109$$

and of

$$(3)\quad G_o = 30$$

Solving equations (1), (2) and (3) simultaneously we obtain

$$(4)\quad \tfrac{1}{4}\ G_m + 1/16\ I_m = 20 \text{ or } G_m + \tfrac{1}{4}\ I_m = 80$$

Now if I_m is considered negligible, equation (4) implies that differences between the additive genotypes of the mares account for $\frac{80}{109}$ or 73 percent of the total variance of gestation lengths. On the other hand to the extent that I_m is not considered negligible the differences between genotypes of the mares (not limited to additive effects) accounts for an amount in excess of 73 percent.

In view of the number of data involved, this suspiciously large estimate of the importance of genotypic differences between mares does not seem explainable solely on the basis of sampling error. That is to say, the results suggest that this estimate may be biased. A bias leading to too large an estimate of the type being discussed could logically

result from the ignoring of effects of sex linked genes upon the character in question. To the extent that a disproportionately large number of the genes in the mare's genotype for gestation length are sex linked, the coefficient of G_m in (1) will change from ¾ to a lower limit of ½. By comparison of equations (1), (2) and (4) it is obvious that such a change in the value of the coefficient of G_m in (1) will result in a smaller estimate of g_m^2 (the proportion of the variance due to differences between the additive genotypes of mares). The authors feel that the evidence suggests the possibility that a disproportionately large number of the mare's genes involved in conditioning the duration of her pregnancies may be sex linked. Earlier in this paper we presented some evidence for a similar situation with respect to the genotype of the foetus.

In evaluating the evidence here presented for sex linkage one can postulate the existence of a set of sex linked genes with expression in the foetal state and a different set with expression in the sexually mature mare. Or one can postulate a single set of such genes with pleiotropic action in the sense that they may have some manifestations (probably endocrine in nature) in the foetus and again when the female foetus has become a mature adult and is carrying her foetus. Cole *et al.* (1933) demonstrated the presence of oestrin in fetal horse tissues of both sexes. They suggested: ". . . the possibility that the large amounts of oestrin excreted by the mare in the urine during the second half of pregnancy, when the maternal ovaries are quiescent, may be of fetal origin."

In analyzing the evidence for sex linkage in the fetal genotype we stated that the extent to which S (for female paternal half sibs) exceeds S (for male paternal half sibs) will be an index of the relative importance of sex linked genes in conditioning the trait under consideration. We found S (for females)=5.27 and S (for males)=3.12. Düring (1937) in his study of gestation lengths of Swedish Friesian cattle analyzes the variance between paternal half sib families for bull calves and heifer calves separately. For 454 heifer calves sired by seven sires S=4.13 and for 465 bull calves sired by the above seven sires S=3.11. These results as can be seen are similar to our findings for the horse.

Summary

Evidence is presented that in Arabian horses the genotype of the foetus affects the length of gestation. This, of course, implies an influence of the stallion. The magnitude of this effect in records cor-

rected for seasonal effect and level of nutrition of the mare was similar to reports for other breeds of horses and for dairy cattle and sheep. The heritability estimate obtained from these adjusted records was 36 percent.

Analysis of the authors' data and other data in the literature suggests the possible importance with respect to gestation length of sex linked genes in both the genotype of the foetus and of the mare.

A partitioning of the total phenotypic variance of gestation lengths into genetic and non-genetic factors yielded the following estimates of the relative importance of these sources of variation:

Season of breeding accounted for 43.4 percent of the total variance, level of nutrition of the mare 5.2 percent, additive genotype of the foal 18.3 percent, dominance deviations from the additive scheme 7.1 percent, permanent maternal traits 12.2 percent, and residual unanalyzed causes 13.8 percent.

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THE RIBOFLAVIN REQUIREMENTS OF GROWING SWINE

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ALTHOUGH riboflavin is important in the normal nutrition of pigs it has received only relatively minor attention. Most investigations of the riboflavin nutrition of pigs have involved purified diets and dealt with growing pigs. Several experiments have been reported in which weanling pigs have been studied for 10 weeks but little is known of the requirements beyond this period.

Hughes (1939) found that riboflavin was necessary in the nutrition of pigs and later (1940) reported that between 1 and 3 milligrams per hundred pounds body weight was the daily minimum requirement. He used purified diets in his experiments. Krider, Terrill and Van Poucke (1949) reported the practical minimum level to be approximately 1.4 milligrams per pound of feed in experiments using both synthetic and natural diets. Mitchell, Johnson, Hamilton and Haines (1950) measured the effect of temperature on the riboflavin requirement of growing pigs and reported that at 85° F., 0.54 milligram per pound of diet was adequate as judged by body weight gains and the percentage of neutrophils in the total leukocytes. However, they found that at 42° F. approximately 0.82 milligram was required if based on body weight gains or 1.04 milligrams if based on the percentage of neutrophils of the total leukocyte count. These workers used semi-synthetic diets in their experiments. The National Research Council Committee on Animal Nutrition, Hughes et al. (1950) recommends a level of 0.80 milligram of riboflavin per pound of diet. The three experiments described in the present report support the recommendation just mentioned in that 0.83 milligram of riboflavin per pound of diet proved adequate for growing swine for 20 weeks or more.

Experimental Procedure

Experiments were planned to determine the riboflavin requirements of growing pigs on practical diets under natural environmental conditions and for use in a further study of riboflavin requirements during gestation and lactation.

[1] The authors are grateful to Mr. Ivan Lindahl and Mr. C. E. Faulkner for the riboflavin assays.
[2] Bureau of Animal Industry.

Four levels, namely; 0.55, 0.83, 1.25 and 1.65 milligrams, of riboflavin per pound of diet were used. This selection of levels was based on the amount recommended by the National Research Council and includes the amounts found necessary for growing pigs by Krider *et al.* (1949) and Mitchell *et al.* (1950). The composition of the diets is shown in table 1.

These diets were used for the weanling pigs, the protein content being reduced as the pigs became heavier. It was necessary to use hominy grits (white or yellow) and to reduce the amount of alfalfa

TABLE 1. COMPOSITION OF DIETS USED

Component		Diet A	Diet B	Diet C	Diet D
Yellow corn meal	%	....	....	70.0	70.0
Hominy grits	%	72.5	70.5	....	....
Soybean meal	%	11.5	10.5	10.5	10.5
Linseed meal	%	6.0	6.0	6.0	6.0
Alfalfa meal	%	0.5	4.0	6.0	6.0
Tankage	%	7.5	7.4	6.0	6.0
Mineral mixture	%	1.5	1.5	1.5	1.5
A & D feeding oil	%	0.5	0.1	....	....
Riboflavin concentrate (as needed)		—	—	+	+
Ca. pantothenate mg./lb.		1.0	0.5	....	....
Protein content	%	18.0	18.0	18.0	18.0
Riboflavin content mg./lb.		0.55	0.83	1.25	1.65

meal to obtain 0.55 and 0.83 milligram of riboflavin per pound of feed. The ingredients used in the diets were analyzed in the laboratory by a chemical method (Loy, 1949) before computing the final diet. Samples taken from the mixed diets and analyzed for riboflavin were in close agreement with the above levels.

In the first, or preliminary, experiment 24 pigs from three litters of eight each, weighing an average of 75 pounds, were used. Since these pigs were older and heavier than weanling pigs, they were partly depleted of riboflavin stores by feeding a semi-synthetic diet very low in riboflavin for two weeks and, were then fed the diets containing the four levels of riboflavin for 10 weeks. They were individually fed in raised pens with screen floors an amount equal to 4.5 percent of their body weight. Barn temperature during this experiment was kept at approximately 60° F.

Twenty-four female weanling pigs, weighing an average of 30 pounds, were used in a second experiment begun on June 3, 1949. Only 14 litter mates were available for this experiment. The other 10 pigs were selected as uniformly as possible from other litters. These pigs were group-fed in self feeders the natural diets containing the four levels of riboflavin. To avoid excessive fattening of the gilts for the gestation and lactation period, it was necessary to limit the daily feed when the groups averaged about 200 pounds in weight.

In a third experiment beginning on May 3, 1950, 32 female pigs weighing an average of 27 pounds were used. Litter mates were available in groups of four from eight litters. These were also group-fed as in the second experiment, except that limited feeding began earlier, at approximately 180 pounds group average. In this test 0.3 percent of an animal protein factor supplement recognized as containing aureomycin and vitamin B_{12} was included in the four diets. Concrete floor pens were used in the second and third experiments. They were hosed down at frequent intervals.

Results and Discussion

Environmental temperature appears to be an important factor in the riboflavin requirements of growing swine, but in these experiments it was not practical to conduct the experiment at a fixed temperature for the number of animals and the time involved. Results obtained here are in agreement with those reported by Mitchell *et al.* (1950), which have been discussed earlier in this paper. The mean temperatures during these experiments were probably near the mean of the two temperatures used in their work.

The present experiment for determining the riboflavin requirements of growing swine have the advantages of ordinary environmental conditions and practical diets. High cost of synthetic diets was a factor influencing the choice of natural diets. Also, feeding of synthetic diets would possibly cause uncontrolled deficiencies, especially during gestation and lactation.

Determination of the riboflavin requirements, composite results of which are shown in table 2, were based on gain in body weight. Deficiency symptoms further confirmed the difference between adequate or inadequate levels. Symptoms of riboflavin deficiency occurred only on the level of 0.55 milligram of riboflavin per pound of feed. Deficiency symptoms that appeared include retarded growth, poor appetite, rough hair coat, rough skin sometimes caked with a sebaceous exudate, secre-

TABLE 2. RESPONSE OF PIGS FED DIETS CONTAINING 0.55 TO 1.65 MILLIGRAMS OF RIBOFLAVIN PER POUND OF FEED (SUMMARY OF THE THREE EXPERIMENTS)

Items compared	Results at 10 weeks on diet				Results at 20 weeks on diet			
	A	B	C	D	A	B	C	D
Riboflavin content of ration mg./lb.	0.55	0.83	1.25	1.65	0.55	0.83	1.25	1.65
Number of pigs[1]	19	19	19	19	13	13	13	13
Initial weight per pig, lbs.	40.4	40.6	40.8	40.2	28.5	28.9	28.5	28.0
Final weight, lbs.	97.3	125.1	129.6	126.5	145.2	209.1	222.3	214.3
Average daily gain, lbs.	.81±.10[2]	1.21±.03	1.27±.09	1.24±.09	.83±.12	1.29±.10	1.39±.04	1.32±.06
Feed per pound gain, lbs.	3.23	2.97	2.89	2.84	3.40	3.44	3.46	3.43

[1] One pig was removed from each group for reasons not related to the riboflavin treatment. The reduced numbers of pigs in the results at 20 weeks are due to termination of the first experiment at the end of 10 weeks of feeding.

[2] Standard error.

tion around the eyes and infrequent periods of diarrhea. Two pigs died during the experiments due to the deficiency. The deficient pigs responded to riboflavin therapy during a brief period in the first experiment.

During the first 10 weeks of the feeding period, the pigs fed 0.55 milligram of riboflavin required more feed to produce a pound of gain than those fed the larger amounts. There were no significant differences in feed requirements among the three higher levels. The pigs in group A made significantly slower daily gains than those in groups B, C and D through both the 10 and the 20 week periods, the probability being greater than 1 to 99. Differences in daily gains among groups B, C and D were not significant even on the basis of a probability of 1 to 19.

The data accordingly indicate that 0.55 milligram of riboflavin per pound of diet was inadequate for normal growth, whereas amounts higher than 0.83 milligram failed to produce appreciably better gains than this level. How near the 0.83 milligram level lies to the border line of an adequate amount is not definitely known but with a small difference between the levels fed the A and B groups, it appears that 0.83 milligram would be the practical minimum requirement. Feed efficiency was slightly improved during the first 10 weeks by an increased amount of riboflavin up to the amount fed the C group.

The riboflavin content of diet C without the addition of a riboflavin concentrate averages slightly more than 1.0 milligram per pound, which would supply the requirement. Diet C is considered a more practical swine diet than diet B.

Summary

The results of these experiments show that 0.83 milligram of riboflavin per pound of diet in dry lot is adequate for growing swine. This amount is supplied from practical diets but probably not in any great excess. An amount of 0.55 milligram of riboflavin per pound of feed was inadequate for growth and caused symptoms of riboflavin deficiency.

There was an indication that riboflavin is associated with utilization of feed during the first 10 weeks of growth.

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THE SUPPLEMENTARY VALUE OF RIBOFLAVIN, CALCIUM PANTOTHENATE AND NIACIN IN A PRACTICAL MIXED ANIMAL AND PLANT PROTEIN RATION CONTAINING B_{12} AND AUREOMYCIN FOR WEANLING PIGS IN DRY LOT[1]

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EARLY work of Chick *et al.* (1938), Hughes (1939), Hughes (1940), Hughes and Ittner (1942), and Hughes (1943), fully demonstrated that riboflavin, pantothenic acid, and niacin were essential in the proper nutrition of the pig. Hughes and co-workers were the first to establish minimum levels of the three B-vitamins in a synthetic (purified) ration for weanling pigs. Later pig studies by Krider *et al.* (1946, 1949) strongly suggested a practical minimum level of 1.4 mg. of riboflavin per lb. of total ration for weanling pigs in dry lot, compared with the recommendation of 0.8 mg. of riboflavin per lb. by Hughes (1940) and by the National Research Council (1950). Luecke *et al.* (1947, 1948) and Powick *et al.* (1947) found that the nicotinic acid requirement was much higher for pigs fed natural than synthetic rations. McMillen and Luecke (1948) and Luecke *et al.* (1947, 1949, 1950) showed that practical (natural) rations do not always furnish adequate amounts of pantothenic acid for the optimum growth of the pig.

Supplementation of a corn-soybean meal ration for pigs fed in dry lot with the various well-known crystalline B-vitamins significantly improved the growth rate, feed efficiency, and blood picture according to the studies of Krider *et al.* (1948) and Luecke *et al.* (1947, 1948). Further work by Dyer, Krider, and Carroll (1948) and McMillen, Luecke, and Thorp, Jr. (1949) presented good evidence that supplementation of an all-plant protein ration for dry-lot fed pigs with riboflavin, pantothenic acid, and niacin was equally as effective as supplementation with several other additional B-vitamins. In the same study McMillen and co-workers demonstrated that the addition of a mixture of 20 mg. nicotinic acid, 15 mg. calcium pantothenate and 5.0

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mg. riboflavin per lb. to a mixed animal and plant protein ration markedly improved growth rate and feed efficiency, and prevented diarrhea, goosestepping, and other B-vitamin deficiency symptoms in 7-week-old weanling pigs fed on concrete floors. Single additions of the three B-vitamins to the basal ration failed to improve the performance of the pig. The basal ration furnished 1.12 mg. riboflavin, 5.04 mg. pantothenic acid, and 12.15 mg. niacin per lb. according to conventional microbiological assays. Luecke *et al.* (1949) related the deficiencies of the three B-vitamins with a so-called nutritional enteritis in farm-raised pigs which were effectively cured by intraperitoneal injections and subsequent oral feeding of the three B-vitamins.

In the past, swine research has dealt mainly with the value of B-vitamin supplementation of high quality all-plant or mixed animal and plant protein rations fortified only with essential minerals and vitamins A and D for pigs in dry lot. In light of new knowledge concerning growth-stimulating factors, the present experiment reported herein was set up to determine whether any or all of the three B-vitamins will further improve a high quality mixed animal and plant protein ration which has been well fortified with vitamin B_{12} and an antibiotic, aureomycin, as well as with essential minerals, and vitamins A and D.

Experimental

Pigs Used

Forty purebred Duroc weanling pigs averaging 30 lb. in weight at the start of the trial were grouped equally into four treatment lots. Equal number of barrows and gilts were placed in each lot. The pigs were selected from sows that had been fed an excellent mixed animal and plant protein ration in dry lot during gestation and on pasture during lactation. The excellent nutritional history of the sows probably permitted a good "vitamin reserve" storage in pigs by weaning time. The experimental pigs were self fed continuously on concrete floors until each group averaged 220 lb. in weight.

Basal Ration Fed

The composition of the basal ration fed in this trial which started June 13, 1950, is shown in table No. 1.

The basal ration was analyzed and found to contain 20.3% total protein and 12.5 ppm. of manganese. In accordance with National

Research Council (N.R.C.) standards, the level of protein in the ration was reduced as the pigs matured. A simple mineral mixture of 40 parts ground limestone, 40 parts steamed bone meal, and 20 parts iodized salt was fed free choice. The estimated B-vitamin values of the basal ration indicate that it amply meets the N.R.C. requirements (1950) of 0.8 mg. riboflavin and 5.0 mg. niacin per lb. of ration but falls below the N.R.C. requirement of 4.5 mg. calcium pantothenate per lb. of

TABLE NO. 1. COMPOSITION OF BASAL RATION

Ingredients	% of Ration[3]
Ground yellow corn	68.25
Soybean meal, expeller	12.40
Fishmeal	6.20
Meat and bone scraps	6.20
Cottonseed meal	3.10
Alfalfa Meal (dehydrated)	3.10
Vitamin A and D oil	0.25
Lederle's APF[1]	0.50
Total	100.00
Manganese (ppm.)	12.50
Total protein (per cent)	20.30
Riboflavin (mg. per lb.)[2]	1.13
Niacin (mg. per lb.)[2]	12.26
Calcium pantothenate (mg. per lb.)[2]	3.36

[1] Contained approximately 2.5 mg. B_{12} and 1.7 mg. of aureomycin per lb.
[2] Estimated values using average vitamin content for each feed ingredient.
[3] Mineral mixture of ground limestone, steamed bone meal and iodized salt was fed free choice.

total ration. Naturally this is based on the assumption that the B-vitamins contained in the ration are highly available to the animal.

Treatments

Various combinations of the three well-known crystalline B-vitamins were tested in the basal ration. The treatments employed were as follows:

Lot 1. Basal ration
Lot 2. Basal ration + 0.8 mg. riboflavin per lb.
Lot 3. Basal ration + 4.5 mg. calcium pantothenate per lb.
Lot 4. Basal ration + 0.8 mg. riboflavin + 4.5 mg. calcium pantothenate + 5.0 mg. niacin per lb.

All of the crystalline and crude vitamin supplements were premixed in soybean meal before they were added to the total ration.

Results

The results of adding the three B-vitamins in various combinations to a well-fortified ration for young pigs in dry lot are shown in table No. 2.

Pigs fed the basal ration (lot 1) made an excellent daily gain of 1.76 lb. on a feed requirement of 386 lb. per 100 lb. gain. The addition of 0.8 mg. riboflavin per lb. of basal ration (lot 2) or of 4.5 mg. of calcium pantothenate per lb. of basal ration (lot 3) produced no significant

TABLE NO. 2. THE SUPPLEMENTARY VALUE OF RIBOFLAVIN, CALCIUM PANTOTHENATE, AND NIACIN IN A PRACTICAL RATION FOR WEANLING PIGS IN DRY LOT—SUMMER, 1950

	Treatment	Av. Daily Gain[1] lb.	Total Feed per 100 lb. Gain lb.	Days to reach 220 lb.
Lot 1	Basal Ration	1.76	386	107
Lot 2	Basal Ration + 0.8 mg. riboflavin per lb.	1.83	362	103
Lot 3	Basal Ration + 4.5 mg. calcium pantothenate per lb.	1.83	345	103
Lot 4	Basal Ration + 0.8 mg. riboflavin + 4.5 mg. calcium pantothenate + 5.0 mg. niacin (per lb.)	1.93	336	98

[1] L.s.d., 5% level—0.14 lb.; 1% level—0.19 lb.

increase in growth response, but resulted in a slight saving in feed requirement per unit gain. Even though our basal ration did not meet the requirement of calcium pantothenate set up by the N.R.C., the addition of this vitamin singly to the diet had no beneficial effect. The supplementation of the basal ration with 0.8 mg. riboflavin, 4.5 mg. calcium pantothenate, and 5.0 mg. niacin per lb. of total ration (lot 4) significantly increased the daily gain to 1.93 lb., or about 10 per cent, and reduced the total feed requirement to 336 lb. per 100 lb. gain, or about 13 per cent. The pigs in lot 4 also reached market from 5 to 9 days earlier than those in lots 1, 2, and 3. These data indicate even when weanling pigs are fed an excellent combination of high quality protein supplements in a grain ration fortified with essential minerals, vitamins including B_{12}, and an antibiotic, the addition of the three

crystalline B-vitamins will further improve pig growth and feed efficiency in dry lot. The apparent synergistic action of the three B-vitamins in the above high quality protein ration is very similar to that observed by McMillen *et al.* (1949). The Michigan workers increased the average daily gain of seven-week-old pigs from 0.63 to 1.0 lb. and reduced the total feed requirement from 401 to 314 lb. per 100 lb. gain by adding high supplementary amounts of the three B-vitamins to a basal ration of corn, soybean meal, meat scraps, alfalfa meal, minerals, but containing no fishmeal, B_{12} supplement, or antibiotic. The levels of B-vitamins added in this Michigan study were practically therapeutic doses, compared with lower protective levels fed in our own pig study. Single additions of the three B-vitamins to the basal ration failed to stimulate growth rate of young pigs fed in dry lot for only nine weeks in the same Michigan study. Even though the growth rate of the best lot receiving the three B-vitamins in the Michigan experiment did not equal the best gain obtained in the experiment reported herein, the Michigan work indicated that any one of the three B-vitamins might become a limiting factor on the utilization of the other two in mixed animal and plant rations for pigs. However, it should be emphasized that the results obtained at the Michigan station and our own station do not fully establish the optimum requirement of riboflavin, calcium pantothenate and niacin for maximum growth and feedlot performance in weanling pigs.

Lots 1, 2 and 3 had very similar growth trends based on the cumulative two-week gains during the 98-day feeding period. Lot 4 also grew at about the same rate as the other three lots during the first 56 days of the experiment, after which lot 4 started to outgain the other three lots and continued to do so throughout the rest of the experiment. This growth trend in lot 4 may be explained on the "heavy" residual stores of vitamins in weanling pigs at the start of the trial which were not depleted sufficiently to obtain a supplemental vitamin effect until after about 8 weeks.

The pigs in all lots exhibited no scours, abnormal gaits, or any other specific B-vitamin deficiencies during the 14-week experimental period. The growth response was quite uniform within all four groups and the appetites were good.

Summary

Weanling 30-lb. pigs were self-fed a basal ration of yellow corn, expeller soybean oil meal, fishmeal, meat and bone scraps, cottonseed

meal, alfalfa meal, a B_{12}-aureomycin feeding supplement, vitamin A and D oil, and a simple mineral mixture (free choice) on concrete floors.

The simultaneous addition of 0.8 mg. riboflavin, 4.5 mg. calcium pantothenate, and 5.0 mg. niacin per lb. to the basal ration increased the average daily gain by 10 percent, reduced the feed per 100-lb. gain by 13 percent, and produced hogs for market about 9 days sooner.

Single additions of either riboflavin or calcium pantothenate to the high quality pig ration failed to improve growth rate markedly and exerted only a slight favorable effect on feed efficiency.

No diarrhea or any gross symptoms of a vitamin B-Complex deficiency were observed in any of the groups.

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FURTHER STUDIES ON THE SUPPLEMENTARY VALUE OF AUREOMYCIN, STREPTOMYCIN, AND VITAMIN B_{12} IN A PLANT PROTEIN RATION FOR GROWING-FATTENING PIGS[1]

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PAST research pertinent to vitamin B_{12}, streptomycin, or aureomycin in pig nutrition has been critically reviewed in a recent paper by Briggs and Beeson (1951). In this same paper, the authors definitely showed that Lederle's B_{12}-aureomycin feeding supplement produced a greater growth response in pigs than Merck's B_{12} concentrate. Since the two supplements were fed to supply about the same vitamin B_{12} activity in a practical pig ration, the data strongly suggests the existence of additional growth-stimulating factor or factors, one of which is aureomycin. Evidence was also obtained on the interrelationship of vitamin B_{12} and pure streptomycin in producing marked stimulation of growth in pigs (1950). Simultaneously, Ferrin and Anderson (1950) reported conflicting results on the combined effects of B_{12} and streptomycin. In the same experiment, the Minnesota workers observed a synergistic effect of vitamin B_{12} and aureomycin on growth rate of pigs in a 70-day feeding trial. Oleson *et al.* (1950) found a definite mutual sparing action of aureomycin and vitamin B_{12} in a fortified all-plant protein ration for young chicks. This finding was followed by a report of Stokstad and Jukes (1951) in which they observed inconsistent results on the sparing action of aureomycin on the vitamin B_{12} requirement of chicks. The research workers suggested that the variability in results may be attributed partly to the nature of the intestinal flora encountered.

Stern and McGinnis (1950) have shown that streptomycin, aureomycin, or terramycin stimulated the growth of rats more than vitamin B_{12} alone when added as supplements to a semi-synthetic ration fed either during the lactation or post-weaning periods. In a brief 28-day pig trial, Carpenter (1950) demonstrated that 12.5 mg. of aureomycin per lb. of total feed gave the same growth stimulation as 12.5 mg. of

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aureomycin plus 10 mcg. of vitamin B_{12} in a mixed animal and plant protein ration for unthrifty pigs. At lower feeding levels of aureomycin (5 mg. per lb.), supplementation with vitamin B_{12} proved to be beneficial. Catron *et al.* (1950) also presented some data which indicated that a combination of vitamin B_{12} and aureomycin, or of vitamin B_{12} and streptomycin, improved pig growth more than single additions of the factors to a plant protein ration for pigs challenged with transmissible gastroenteritis. Nesheim and Johnson (1951) increased the growth rate of baby pigs by the addition of 500 mg. of streptomycin per lb. of dry matter to a nutritionally adequate "synthetic" milk diet with added B_{12}.

In order to secure more confirmatory or clearer evidence of the interrelationship of vitamin B_{12} and pure antibiotics in practical swine rations, a study was set up to measure the effect of adding vitamin B_{12} to a fortified corn-soybean-alfalfa meal ration containing either crystalline aureomycin or streptomycin fed to pigs from weaning to market age.

Experimental

Pigs Used

Fifty purebred Duroc weanling pigs were equally allotted to five treatments. These pigs were farrowed from sows that had been fed well-balanced dry-lot and pasture rations and managed under sanitary conditions during gestation and lactation. The pigs were not depleted of their vitamin B_{12} stores before being started on the test. Approximately equal numbers of barrows and gilts (10–12 weeks old) averaging 44 lb. at the start were used. The pigs were wormed with sodium fluoride before being placed on the experimental rations. The pigs were weighed every 14 days. The experiment which was originally planned to extend from weaning to an average group weight of 200 lb. was terminated at the end of the first 70 days of feeding because of a serious outbreak of bloody dysentery in the basal (control) lot. The other four lots did not become infected with the enteric disease even though they were exposed to the infected group of pigs for the next four weeks.

Basal Ration Fed

The composition of the all-plant protein basal ration is presented in table 1.

The basal ration was analyzed and found to contain 21.80% crude (total) protein and 14.0 ppm. of manganese. The protein level was reduced according to the needs of the pigs as they matured. A mineral mixture of 40 parts steamed bone meal, 40 parts ground limestone and 20 parts iodized salt was fed free choice. The three crystalline B-vitamins were added to the basal ration in amounts shown in footnote of table 1 which fully meet the vitamin allowances recommended by the National Research Council (1950) for weanling pigs.

TABLE 1. COMPOSITION OF BASAL RATION

Ingredients	% of Ration[1]
Ground yellow corn	62.60
Soybean meal, expeller	32.15
Alfalfa meal	5.00
Vitamin A and D oil	0.25
Total	100.00
Manganese (ppm.)	14.00
Total protein (per cent)	21.80
Riboflavin (mg. per lb.)[2]	1.90
Niacin (mg. per lb.)[2]	24.49
Calcium pantothenate (mg. per lb.)[2]	9.90

[1] Mineral mixture of ground limestone, steamed bone meal, and iodized salt fed free choice.
[2] Includes the 0.8 mg. of crystalline riboflavin, 5.0 mg. crystalline niacin, and 4.5 mg. crystalline calcium pantothenate added per lb. of the natural ration plus the estimated amount of each vitamin in the natural ration.

Treatments

Various combinations of streptomycin, aureomycin, and B_{12} were tested in the basal ration. The treatments employed were as follows:

Lot 1. Basal Ration
Lot 2. Basal Ration + 15 mg. streptomycin base per lb.
Lot 3. Basal Ration + 10 mg. aureomycin HCl per lb.
Lot 4. Basal Ration + 15 mg. streptomycin base per lb. + 0.10% Merck's B_{12} concentrate.
Lot 5. Basal Ration + 10 mg. aureomycin HCl per lb. + 0.10% Merck's B_{12} concentrate.

Merck's B_{12} concentrate with a guaranteed potency of 12.5 mg. of vitamin B_{12} activity per lb. supplied about 12.5 mcg. of B_{12} per lb. of total ration when fed at the 0.10% level. The levels of antibiotics fed in this experiment were based mostly upon limited research data at the time of the experiment which indicated that the above levels generally produced a qualitative effect.

The vitamin and antibiotic supplements were pre-mixed thoroughly in soybean meal before they were added to the total ration.

Results

The results of adding aureomycin and streptomycin with and without B_{12} in a plant protein ration for pigs in dry lot are presented in table 2.

Pigs fed the basal plant protein ration with no added B_{12} or antibiotic supplements (lot 1) made an excellent average daily gain of 1.62 lb. on a total feed requirement of 392 lb. per 100 lb. gain during the 70-day feeding period. The addition of either 15 mg. pure streptomycin

TABLE 2. THE SUPPLEMENTARY VALUE OF STREPTOMYCIN, AUREOMYCIN AND VITAMIN B_{12} IN AN ALL-PLANT PROTEIN RATION FOR WEANLING PIGS IN DRY LOT—SUMMER, 1950

Treatment	Av. Daily Gain[1]	Av. Final Weight (70 days)	Av. Daily Feed	Total Feed per 100 lb. Gain
	lb.	lb.	lb.	lb.
Lot 1. Basal Ration	1.62[2]	155	6.36	392
Lot 2. Basal Ration + 15 mg. streptomycin base per lb.	1.80	169	6.01	334
Lot 3. Basal Ration + 10 mg aureomycin HCl per lb.	1.85	174	5.97	322
Lot 4. Basal Ration + 15 mg. streptomycin base per lb. + 0.10% Merck's B_{12} concentrate	1.82	171	6.43	353
Lot 5. Basal Ration + 10 mg. aureomycin HCl per lb. + 0.10% Merck's B_{12} concentrate	1.89	176	6.31	333

[1] L.s.d., 5% level is 0.17 lb.; 1% level is 0.23 lb.
[2] Represents the average daily gain of 9 pigs. One pig died suddenly September 15. Death attributed to rat bait poisoning.

per lb. of total basal ration (lot 2) or 10 mg. pure aureomycin per lb. of total ration (lot 3) significantly improved the growth rate (L.s.d., 5%—0.17 lb.) and reduced the feed requirement from 60 to 70 lb. for every 100 lb. pork produced. The difference in performance of pigs in lots 2 and 3 is not significant. The pigs fed 0.10% Merck's B_{12} concentrate in rations containing 15 mg. streptomycin per lb. (lot 4) or 10 mg. aureomycin per lb. (lot 5) performed significantly better than the basal-fed pigs (lot 1) but only slightly better than pigs receiving only the pure streptomycin or aureomycin supplements. The above results do not concur with previous findings of Briggs and Beeson (1951) which suggested that adequate vitamin B_{12} is required for marked growth stimulation of pigs with pure streptomycin in an all-

plant protein ration. The difference in results of these two experiments may be attributed partly to the half dirt floors of the pens used in the second experiment. These pens were cattle experimental lots which were cleaned thoroughly before the start of the trial. However, the pens contained some left-over manure mixed with the soil. Full concrete floors were used in the first experiment. Perhaps the soil supplied some of the vitamin B_{12}, as suggested by Cunha (1949) and Schneider *et al.* (1950), to fully meet the pig's need, thereby preventing any possible growth response from the added B_{12} concentrate. Another possible explanation is that the older pigs used at the start of the second trial, compared with those of the first trial, permitted greater stores of vitamin B_{12}, thus eliminating the need for supplemental vitamin B_{12} in the pig's ration. Almquist and Merritt (1951) have suggested that vitamin B_{12} stores in their turkey poults may have been a complicating factor in testing the true relationship of vitamin B_{12} and aureomycin on growth. Ferrin and Anderson (1951) report conflicting results on combination effects of streptomycin and vitamin B_{12} on pig growth without a suitable explanation. Therefore, it appears to be of paramount importance that B_{12} depleted stock be used in tests to accurately determine the interdependence of vitamin B_{12} and aureomycin or other antibiotics on growth.

A study of the growth curves of the five lots of pigs in Figure 1 indicates that the antibiotics or antibiotics plus vitamin B_{12} fed under the above experimental conditions exert their most marked effect on pig growth after the first 42 days of the growing-fattening period. The differences between the growth rates of the basal lot (lot 1) and the other four lots are less pronounced during the first 42 days of the growth test period. Another important point is the close similarity of growth trends of the four treated lots from an average weight of 44 lb. to an average weight of 175 to 180 lb.

The pigs fed the antibiotics with and without vitamin B_{12} gained more uniformly than the pigs fed the control ration. The appetites of the pigs were excellent and about the same in all treatments as shown in table 2. There were no evidences of any diarrhea during the 70-day feeding period. This has been observed consistently in all of the trials conducted at the Purdue Station.

The results shown in table 2 do not agree with those reported by Speer *et al.* (1950). The Iowa investigators failed to increase the daily gain or improve feed efficiency of pigs by the addition of 5 or 10 mg. of aureomycin per lb. to a fortified plant protein ration similar to the one used in the above Purdue trial. They attempted to explain the failure

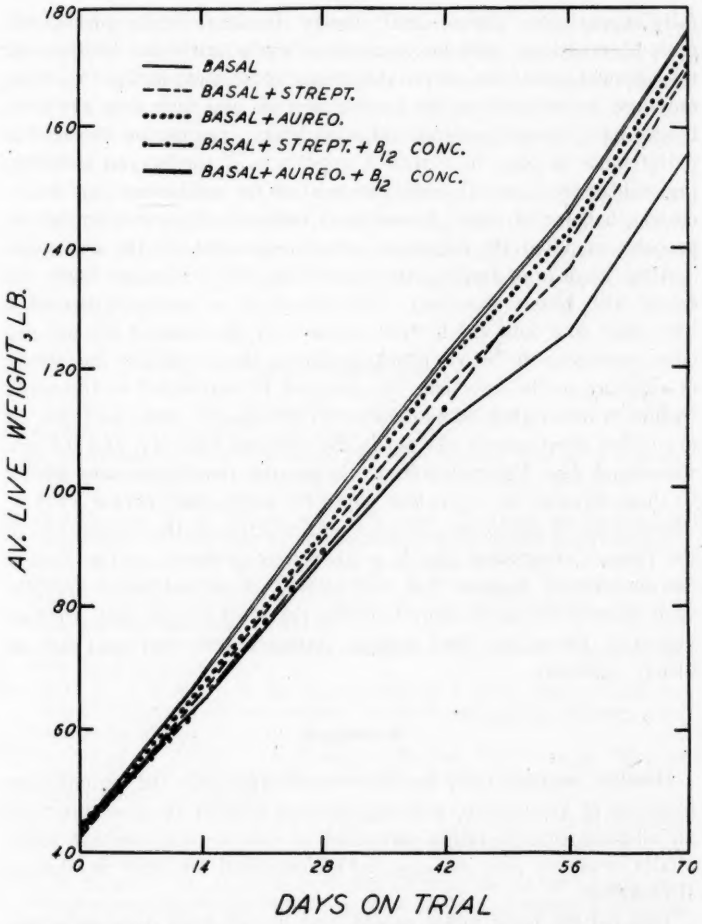

Figure 1. Growth curves of pigs fed various combinations of streptomycin, aureomycin, and B_{12} concentrate in a fortified all-plant protein ration.

of the antibiotic (aureomycin) response in their experiments by the "disease level" theory, i.e., healthy, well-managed pigs may respond less to antibiotic feeding than unthrifty, poor-managed pigs. The results obtained at the Purdue Station on three separate experiments testing the supplementary value of the various antibiotics, however, do not

fully support the "disease level" theory. Healthy, thrifty pigs (from gross observations) with an excellent previous nutritional history and management have been used in the present experiment and in two other antibiotic experiments at the Purdue Station, and each time the antibiotics have exerted a significant stimulatory response on the feedlot performance of pigs. In general it appears as if thrifty and unthrifty pigs will respond to oral feeding of most of the antibiotics, and that a correct balance of other known and unknown dietary essentials is probably required for maximum growth expression of the antibiotic.

After 70 days of feeding, the control lot (lot 1) became badly infected with bloody dysentery. This forced us to terminate the trial. The other four lots which were adjacent to the infected lot did not come down with the bloody dysentery during the subsequent four weeks of exposure to the infection. The infected lot responded to treatment within 48 hours after administration of therapeutic doses of 1 gm. of crystalline streptomycin per pig in the feed the first day, and 0.5 gm. the second day. The responses to therapeutic treatments were similar to those reported in a previous paper by Briggs and Beeson (1951). The absence of this particular intestinal infection in the treated lots in the present experiment and in a previous experiment at the Purdue Station strongly suggests that oral feeding of the antibiotics continuously throughout the growing-fattening period of the pig may exert an important protective effect against certain enteric diseases, such as bloody dysentery.

Summary

Healthy, vigorous forty-four-lb. weanling pigs were fed various combinations of aureomycin, streptomycin and vitamin B_{12} concentrate in an all-plant protein ration composed of yellow corn, soybean meal, alfalfa meal, cod liver oil, essential minerals and the three well-known B-vitamins.

Pigs fed the basal ration gained 1.62 lb. per head daily on a feed requirement of 392 lb. per 100 lb. gain. The addition of 15 mg. of pure streptomycin per lb. of total ration or of 10 mg. of pure aureomycin per lb. significantly increased the average daily gain about 11 to 13% and increased the feed efficiency about 14 to 16%.

The addition of 12.5 mcg. vitamin B_{12} per lb. of total ration (0.1% Merck's B_{12} supplement) to the basal ration containing either aureomycin or streptomycin improved the growth significantly above the basal ration but only slightly above the ration containing either antibiotic.

The slight growth stimulatory effect of vitamin B_{12} in the presence of the antibiotic observed in this trial, compared with that observed in a previous experiment, may be attributed either to the greater reserve storage of vitamin B_{12} in the heavier pigs used at the start of the test, or to the vitamin B_{12} in the soil and left-over manure in the half-paved cattle lots, or both.

The supplementation of the practical (basal) ration for pigs with each of the two antibiotics and/or vitamin B_{12} produced more uniform response, and provided some natural protection against bloody dysentery which infected the basal-fed pigs during the last 4 weeks of the experiment.

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COMPARISON OF SOLVENT SOYBEAN OIL MEALS AND THE EFFECT OF DRIED WHEY PRODUCTS AND ANTIBIOTICS IN DRYLOT RATIONS FOR PIGS[1]

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RESEARCH at the Illinois Station by Dyer and Krider (1950) showed that the substitution of a "special" solvent soybean oil meal (heated for 30 minutes at atmospheric pressure in the presence of live steam) for regular solvent soybean oil meal in a drylot ration (20% crude protein) which also contained ground yellow corn and was fortified with minerals, vitamins A and D and six B-complex vitamins (thiamine, riboflavin, niacin, pantothenic acid, pyridoxine and B_{12} concentrate) did not significantly alter the rate of gain of weanling pigs.

Krider *et al.* (1949) obtained significant increases in growth rates of weanling pigs when either 2 or 4% dried whey-product with whey fermentation solubles was added to a corn-soybean oil meal ration that contained 5% meat and bone scraps. When the basal ration included six B-vitamins the addition of 5% meat scraps plus 2% dried whey-product with whey fermentation solubles resulted in a highly significant increase in rate of gain to 75 pounds (Dyer *et al.*, 1949). The essentiality of vitamin B_{12} for pigs has been reported by numerous investigators. Vohs *et al.* (1951), using a basal ration similar to the one used by Dyer et al. (1949), reported that the addition of 2% dried whey, with and without 15 micrograms of vitamin B_{12} per pound of ration, significantly increased average daily gains of growing-fattening pigs fed in drylot, further indicating that dried whey supplies growth factor(s) other than, or in addition to, vitamin B_{12}. The responses of pigs are similar to those reported in poultry researches (Hill, 1948; Hill and Branion, 1950; and Menge, 1949).

Moore *et al.* (1946) found that the inclusion of streptomycin in the diet of the chick resulted in a significant growth response. Luecke *et al.*

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(1950) reported that the addition of 0.05% streptomycin to a fortified corn-soybean oil meal ration increased the rate of gain of weanling pigs. The growth response produced in swine by adding crystalline aureomycin to the ration was reported by Jukes, *et al.* (1950). Terrill and Krider (1950) reported that the addition of crystalline aureomycin to a "corn-soybean oil meal" ration for pigs increased gains very significantly. Other workers have confirmed the ability of antibiotics to stimulate rate of gain in pigs.

Objects of Experiments

Experiment 1.

The objectives were (1) To compare regular solvent soybean oil meal, a "special" solvent soybean oil meal processed for 45 minutes at atmospheric pressure in the presence of live steam, and a high-protein dehulled solvent soybean oil meal in a "corn-soybean oil meal" ration fed to weanling pigs in drylot and (2) To study the supplementary effect of the addition of 5% dried whey-product with whey fermentation solubles, 5% dried whey-product with whey fermentation solubles and vitamin B_{12} concentrate, or 25 mg. aureomycin hydrochloride per pound to a ration containing high-protein solvent soybean oil meal.

Experiment 2.

The objectives were (1) To study the effect on rate and efficiency of gain and on physical carcass characteristics of adding 10, 20 or 40 mg. of streptomycin per pound of ration fed to growing-fattening pigs in drylot from 75 to 225 pounds in live weight and (2) To determine the concentration of streptomycin in samples of fat, lean meat and blood serum from hogs fed the above levels of streptomycin.

Experimental Procedure

Experiment 1.

Six lots of ten pigs each were self-fed a 20% crude protein corn-solvent soybean oil meal ration in drylot (concrete) from weaning to 75 pounds in live weight. The pigs had been raised to weaning by sows fed adequate rations on rye pasture during lactation, and all pigs had access to creep rations. The rations fed are given in table 1. Each pig was removed from test on the weigh day that it weighed approximately 75 pounds.

TABLE 1. RATIONS FED TO WEANLING PIGS IN EXPERIMENT 1 (SPRING 1950)

Ingredients	Lot numbers					
	1	2	3	4	5	6
	Regular solvent soybean oil meal ration	"Special" solvent soybean oil meal ration	Hi-protein solvent soybean oil meal ration	3 + 25 mg. aureomycin HCl per pound	3[1] + 5% dried whey product with whey fermentation solubles	3[1] + 5% dried whey product with whey fermentation solubles and B_{12} conc.
			Percent			
Ground yellow corn	64.2	64.2	69.7	65.8	65.8	69.7
Regular solvent soybean oil meal[2]	32.5	....	....	....	....	....
Special solvent soybean oil meal[3]	....	32.5	....	....	....	....
Hi-protein solvent soybean oil meal[4]	....	....	27.0	27.0	26.0	26.0
Steamed bone meal	1.0	1.0	1.0	1.0	1.0	1.0
Mineral mixture (H & K)[5]	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin A & D concentrate[6]	0.2	0.2	0.2	0.2	0.2	0.2
Dried whey-product with whey fermentation solubles[7]	....	....	....	....	5.0	....
Dried whey-product with whey fermentation solubles plus vitamin B_{12} concentrate[8]	....	....	....	....	....	5.0
Vitamin B_{12} feed supplement[9]	0.1	0.1	0.1	0.1	....	....
B-vitamin additions[10]	+	+	+	+	+	+
Aureomycin HCl	....	....	....	+	....	....

[1] Without 0.1% vitamin B_{12} feed supplement.
[2] Contained 88.1% dry matter, 1.0% ether extract and 44.2% crude protein by analysis.
[3] Contained 93.0% dry matter, 1.2% ether extract and 47.6% crude protein by analysis.
[4] Contained 89.7% dry matter, 0.7% ether extract and 49.6% crude protein by analysis.
[5] Mineral mixture reported by Dyer *et al.* (1949) JOURNAL OF ANIMAL SCIENCE 8:542.
[6] Guaranteed to contain 5000 I.U. of vitamin A and 1000 I.U. of vitamin D per gram.
[7] Contained 58.8% lactose monohydrate, 14.9% crude protein, 13.0% ash, 6.2% lactic acid, and 23.0 mg. riboflavin per pound.
[8] Pro-Twelve product contained 62.8% lactose monohydrate, 13.1% crude protein, 12.2% ash, 5.3% lactic acid, 41.5 mg. riboflavin per pound and 0.215 mg. vitamin B_{12} per pound.
[9] Guaranteed to contain 12.5 mg. vitamin B_{12} per pound by L.L.D. (cup) assay.
[10] B-vitamin additions per pound of ration were: 1.5 mg. riboflavin, 5 mg. niacin, 6 mg. calcium pantothenate, and 1 gm. choline chloride powder (25% choline chloride).

Experiment 2.

As the last 33 pigs completed experiment 1 they were reallotted into 4 groups on the basis of breed, sex, litter, weight and previous experimental treatment to study the effect of adding 10, 20 or 40 mg. of streptomycin per pound of ration for growing-fattening pigs in drylot from 75 to 225 pounds in live weight. The basal rations fed are given in table 2.

Each pig was slaughtered on the weigh day that it weighed approximately 225 pounds. Carcass measurements and weights were taken after the carcasses had remained in a cooler at 32° F. for approximately 48 hours. Blood samples were procured at slaughter time from the last pig slaughtered from lots 1, 3 and 4. A representative sample

TABLE 2. BASAL RATIONS FED TO GROWING-FATTENING PIGS IN EXPERIMENT 2 (SUMMER, 1950)

Ingredients	Live weight of pigs	
	75 to 125 lb.	125–225 lb.
	%	%
Ground yellow corn	70.5	76.5
Meat scraps (55% protein)	5.0	5.0
Dried corn distillers' solubles	5.0	5.0
Dehydrated alfalfa meal	5.0	5.0
Solvent soybean oil meal	14.0	8.0
Trace-mineralized salt	0.5	0.5

of back fat and loin tissue was obtained from each carcass when the carcass measurements were taken. Samples were frozen and composited by lots. Blood serum, back fat and loin tissue were assayed quantitatively for streptomycin.[5]

Results and Discussion

Experiment 1.

The results of experiment 1 are briefly summarized in table 3. The three solvent soybean oil meals[6] were equally effective in promoting rate of gain when fed to weanling pigs in drylot rations containing 20% crude protein. Dyer and Krider (1950) have reported that solvent soybean oil meal promoted significantly more rapid gains than expeller soybean oil meal when fed in drylot rations to weanling pigs.

[5] Acknowledgement is made to Merck & Co., Inc. for assaying the lean, fat and blood serum samples for streptomycin.

[6] Supplied by A. E. Staley Manufacturing Company, Decatur, Illinois.

TABLE 3. RESPONSE OF WEANLING PIGS TO SOLVENT SOYBEAN OIL MEALS, AUREOMYCIN HCl AND DRIED WHEY-PRODUCTS (SPRING 1950)

	Lot numbers and treatments					
	1	2	3	4	5	6
	Regular solvent soybean oil meal ration	Special solvent soybean oil meal ration	Hi-protein solvent soybean oil meal ration	3 + 25 mg. aureomycin HCl per pound	3[1] + 5% dried whey product with whey fermentation solubles	3[1] + 5% dried whey-product with whey fermentation solubles and vitamin B_{12} concentrate
Number of pigs	11[2]	10	10[2]	10	10	10[2]
Av. initial weight, lb.	32	32	32	32	32	32
Av. final weight, lb.	75	75	76	78	74	75
Av. daily gain, lb. and standard error	1.13±.05	1.14±.04	1.12±.06	1.43±.06**	1.06±.08	1.22±.06
Av. daily feed per pig, lb.	2.98	2.92	2.96	3.54	2.61	3.21
Feed per 100 lb. gain, lb.	266	264	265	251	256	266

** Highly significant (1% level) over lots 1, 2, 3 and 5; significant (5% level) over lot 6.
[1] The 0.1% vitamin B_{12} feed supplement was omitted from the ration as fed in lot 3.
[2] One unthrifty pig removed from test.

The addition of 25 mg. aureomycin HCl[7] per pound of ration (lot 4 versus lot 3) resulted in 28% faster gains (highly significant). Throughout the test it was observed that the pigs receiving aureomycin (lot 4) ate more feed, drank more water and exhibited firmer feces than pigs in the other lots.

Pigs receiving 5% dried whey-product with whey fermentation solubles and vitamin B_{12} concentrate[8] gained 15% faster than pigs receiving this product without the vitamin B_{12} concentrate (lot 6 versus lot 5), but the difference was not statistically significant. The intralot variance for rate of gain in lot 5 was much higher than for other lots

TABLE 4. EFFECT OF ADDING STREPTOMYCIN TO A RATION FOR GROWING-FATTENING PIGS IN DRYLOT (SUMMER, 1950)

Lot number	1	2	3	4
Streptomycin[1] added, mg. per lb. of ration	0	10	20	40
Number of pigs	8[2]	8	9[2]	8
Av. initial weight, lb.	77	77	78	77
Av. final weight, lb.	220	224	220	223
Av. daily gain, lb. and standard error	1.31±.06	1.46±.03*	1.40±.04	1.56±.05**
Av. daily feed per pig, lb.	5.06	5.49	5.45	5.81
Feed per 100 lb. gain, lb.	391	377	390	375

* Significant (5% level) over lot 1.
** Highly significant (1% level) over lot 1 and significant (5% level) over lot 3.
[1] Supplied by Merck & Co., Inc., Rahway, New Jersey.
[2] One unthrifty pig removed from test.

in this experiment. The ration fed in lot 5 was probably deficient or borderline in vitamin B_{12} content. Differences in the body stores of vitamin B_{12} of pigs in lot 5 could account for the higher intralot variance in rate of gain. Since rations fed in lots 3 and 6 contained comparable calculated levels of vitamin B_{12}, the increase in rate of gain of pigs in lot 6 over pigs in lot 3 suggests that there is a supplementary growth factor present in the dried whey-product.

Experiment 2.

The results of experiment 2 are briefly summarized in tables 4 and 5. Pigs receiving 10 mg. streptomycin[9] per pound of ration gained significantly faster (11%) and pigs receiving 40 mg. streptomycin per pound

[7] Supplied by Lederle Laboratories, Pearl River, New York.
[8] Supplied by Western Condensing Company, Appleton, Wisconsin.
[9] Supplied by Merck & Co., Inc., Rahway, New Jersey.

of ration gained very significantly faster (19%) than pigs fed the basal ration. Luecke *et al.* (1950) reported no significant growth response of weanling pigs by adding streptomycin at a level of 10 mg. per pound to a basal ration very similar to the one used in this test. The results of the experiment reported herein would indicate that best results were obtained by the highest level of streptomycin tested.

Dressing percentages for hogs slaughtered from lots 2 and 4 were

TABLE 5. THE EFFECT OF STREPTOMYCIN IN SWINE RATIONS ON PHYSICAL AND CHEMICAL CARCASS CHARACTERISTICS

Lot number	1	2	3	4
Streptomycin added, mg. per lb. of ration	0	10	20	40
Number of pigs slaughtered	5	7	7	6
Live weight, lb.	224.2 ±2.1	223.4 ±0.9	223.4 ±2.5	222.6 ±2.0
Cold carcass weight, lb.	177.7 ±2.1	173.7 ±1.4	174.0 ±2.1	170.6 ±2.1
Dressing percentage	79.3 ±0.5*	77.7 ±0.4	78.0 ±0.3	76.6 ±0.8
Carcass grade[1]	1.2 ±0.2	1.4 ±0.3	1.0 ±0.0	1.0 ±0.0
Carcass firmness[2]	1.2 ±0.2	1.6 ±0.3	1.3 ±0.2	1.3 ±0.2
Thickness of backfat,[3] in.	1.72±0.16	1.56±0.10	1.64±0.13	1.54±0.06
Length of carcass,[4] in.	66.8 ±1.4	68.7 ±1.2	67.4 ±1.6	69.1 ±0.9
Length of body,[5] in.	29.3 ±0.5	29.4 ±0.5	28.9 ±0.5	29.2 ±0.4
Depths of body,[6] in.	14.2 ±0.1	13.5 ±0.1	13.5 ±0.1	13.7 ±0.3
Circumference of ham,[7] in.	25.4 ±0.2	25.1 ±0.3	24.6 ±0.4	24.6 ±0.2
Streptomycin content:				
Blood serum, mg. per pint	<0.15	—	<0.15	<0.15
Loin tissue, mg. per lb.	<0.15	—	—	1.3
Backfat, mg. per lb.	<0.15	—	—	0.5

* Significant at 5% level over lots 2 and 4.

[1] Numbers assigned carcass grades were as follows: Choice No. 1, 1; Choice No. 2, 2; and Choice No. 3, 3.

[2] Numbers assigned to carcass firmness grades were as follows: Hard, 1; medium hard, 2; medium soft, 3; and soft, 4.

[3] Backfat thickness was measured at the 1st thoracic, 13th thoracic and 1st sacral vertebrae.

[4] Measured from tip of snout to tip of rear toe.

[5] Measured from anterior point of 1st thoracic vertebra to anterior tip of aitch bone.

[6] Measured with calipers at a point slightly posterior to the elbow joint.

[7] Measured with a string at the natural depression of the tail-ham junction.

significantly lower than for hogs from the basal lot. The hogs were slaughtered directly from the experimental feed lot without a standard shrinkage period or a correction for fill. Therefore, further data are needed before a definite conclusion is drawn regarding the effect of streptomycin on dressing percentage.

There were no significant differences in thickness of backfat or in the other physical carcass measurements made. A very minor accumulation of the antibiotic occurred in the loin tissue and backfat of hogs fed 40 mg. of streptomycin per pound of ration (1.3 mg. streptomycin per pound of loin tissue and 0.5 mg. streptomycin per pound of backfat).

Summary

In a drylot growing-fattening test with weanling pigs a regular solvent soybean oil meal, a "special" solvent soybean oil meal processed for 45 minutes at atmospheric pressure in the presence of live steam, and a high-protein solvent soybean oil meal were equally effective in promoting rate of gain when rations contained 20% crude protein were fed. The addition of 25 mg. aureomycin HCl per pound of ration increased gains very significantly (28%). Pigs receiving 5% dried whey-product with whey fermentation solubles and vitamin B_{12} concentrate gained 15% faster than pigs receiving this product without the vitamin B_{12} concentrate, but the difference was not statistically significant.

In a second experiment the effect on gains and carcass characteristics of adding 10, 20 or 40 mg. of streptomycin per pound of ration fed to growing-fattening pigs in drylot from 75 to 225 pounds in live weight was studied. Pigs receiving 10 mg. streptomycin per pound of ration gained significantly faster (11%) and pigs receiving 40 mg. streptomycin per pound gained very significantly faster (19%) than pigs fed the basal ration. There were no significant differences in thickness of backfat or in other physical carcass measurements studied. There was a very minor accumulation of the antibiotic in the loin tissue and backfat of hogs fed 40 mg. of streptomycin per pound of ration (1.3 mg. streptomycin per pound of loin tissue and 0.5 mg. streptomycin per pound of backfat).

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THE VALUE OF SOLVENT EXTRACTED RICE BRAN IN THE RATIONS OF GROWING-FATTENING SWINE[1]

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RICE bran is the principal by-product of the rice milling industry. It consists of the pericarp layer of the rice grain and a small quantity of hull fragments. Bray (1943) found raw rice bran to contain approximately 12 percent protein, 15 percent fat, 12 percent fiber, 40 percent Nitrogen Free Extract and to have a total digestible nutrient value 84 percent as great as corn.

Bray (1943) reported the results of five feeding trials in which raw rice bran was fed to growing-fattening swine. When rice bran did not exceed 30 percent of the total ration, it was approximately equal to corn in feeding value. The utility of this product was limited by the high degree of unsaturation of the fatty acids. The feed quickly became rancid during storage and produced soft pork when fed to fattening swine.

Commercial extraction of fat from raw rice bran was begun in 1949 and a new product designated "solvent extracted rice bran" became available. This product differs from raw rice bran in being lower in fat, higher in protein, fiber, and N. F. E. This study was designed to evaluate solvent-extracted rice bran.

Experimental Procedure

Forty weanling pigs were equally divided on the basis of weight, sex, and breed into eight lots of five pigs each in an incomplete factorial design. The composition of the rations is shown in table 1.

Rations 1 and 2 were the control rations. Fish meal was a constituent of both rations and, in addition, ration 2 contained an APF supplement.

Rations 3, 4, and 5 contained 15 percent rice bran. The rice bran replaced corn and soybean meal in these rations. Ration 3 is directly comparable to the first control ration; i.e., both contained fish meal and no APF supplement. Ration 4 contained both fish meal and the

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APF supplement, making it directly comparable to ration 2. Ration 5 was an all-vegetable diet containing the APF supplement with no comparable control ration. Rations 6, 7, and 8 contained 30 percent rice bran but are otherwise identical with rations 3, 4, and 5 respectively.

The animals were started on feed December 7, 1950. Self feeders and waterers were used. The animals were kept in outside pens throughout the trial and were weighed at 14-day intervals for 56 days and weekly thereafter.

The number of days required to reach 200 pounds was the main criteria for evaluating the new feed. Weekly weighings did not permit the removal of all animals at exactly 200 pounds; therefore, the

TABLE 1. COMPOSITION OF RATIONS[1]

Ration	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8
Ground Yellow Corn	75.0	74.5	63.0	62.5	60.0	51.0	50.5	47.5
Rice Bran	....	....	15.0	15.0	15.0	30.0	30.0	30.0
Fish Meal	5.0	5.0	5.0	5.0	....	5.0	5.0	....
Soybean Meal	15.0	15.0	12.0	12.0	19.5	9.0	9.0	17.0
Dehydrated Alfalfa Leaf Meal	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
APF Supplement	....	0.5	....	0.5	0.5	....	0.5	0.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1] Mineral mixture and salt were allowed free choice to all lots.

average daily gain for the preceding week was used to adjust the number of days required to reach 200 pounds. Although the initial lot mean weights were approximately equal, there was a wide range of individual pig weights. Analysis of covariance (Snedecor, 1946) of the number of days required to reach 200 pounds with initial weights was used to allow for the effects of the initial weight.

Average daily gain was determined by dividing the total gain per lot by the number of days required to reach 200 pounds. Iodine numbers (Hanus) were determined on samples of back and kidney fat. These data were analyzed by the method of analysis of variance described by Snedecor (1946).

Results and Discussion

The number of days required to reach 200 pounds, feed required per 100-pounds gain, average daily feed, average daily gains, and mean iodine numbers are summarized in table 2.

The rations containing both 15 percent and 30 percent rice bran promoted as rapid growth as the control rations.

The APF supplement improved the rations containing fish meal ($P \leq .01$). This is in close agreement with work reported by Beeson and Bloss (1949), Luecke *et al.* (1950), and Vohs *et al.* (1951). It was observed that the incidence of scours was less with those animals receiving the APF supplement. This was demonstrated by Jukes *et al.* (1950). The all-vegetable rations containing the APF supplement (lots 5 and 8) were equal to those containing fish meal without the APF supplement (lots 1, 3, and 6).

TABLE 2. RESPONSE OF PIGS TO TWO DIFFERENT LEVELS OF RICE BRAN WHEN FED IN DIFFERENT FEED COMBINATIONS

Item	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8
Level of Rice Bran	....	....	15	15	15	30	30	30
Level of Fish Meal	5	5	5	5	....	5	5	....
Level of APF Supplement	....	0.5	....	0.5	0.5	....	0.5	0.5
Initial Weight	277	278	274	275	275	271	273	274
Gain	723	722	726	725	725	729	727	726
Average Days Required to Reach 200#	89	80	84	74	82	92	76	82
Average Daily Gain	1.62	1.80	1.74	1.97	1.76	1.58	1.91	1.77
Feed Consumption								
Total Consumed	2475	2200	2475	2310	2225	2485	2575	2725
Av. Daily Consumption	5.6	5.5	5.9	6.3	5.4	5.4	6.8	6.6
Pounds Feed Per 100# Gain	342	305	341	319	307	341	354	375
Average Iodine Numbers								
Back Fat	64.8	65.2	63.6	64.5	64.2	66.0	65.0	65.5
Kidney Fat	56.8	56.8	57.1	57.0	57.5	60.0	61.0	58.0

The daily feed consumption was, in general, in the order of the rates of growth. The animals receiving ration 8 tended to waste more feed than the other animals on the experiment. This may account, in part, for the higher consumption and lower efficiency recorded for this group.

The lots receiving 15 percent rice bran utilized their feed as efficiently as did the lots receiving the control rations. When rice bran was fed at the 30 percent level, more feed was required to produce a unit gain. The APF supplement improved the efficiency of the animals receiving the control ration and those lots receiving 15 percent rice bran. The feed consumption data were not amenable to a test of significance of the observed differences.

The iodine numbers on both back and kidney fat samples were not altered by either level of rice bran.

Summary and Conclusions

A feeding trial involving forty pigs divided into eight equal lots is reported. Solvent extracted rice bran was fed at two levels in a fairly complete ration. The design was an incomplete factorial which included control rations. Both control rations contained corn as the main cereal grain and fish meal. They differed only in that one had 0.5 percent APF supplement containing vitamin B_{12} and aureomycin.

In three rations the solvent extracted rice bran was included at the level of 15 percent of the total ration. In the other three rations it was included at the level of 30 percent of the total ration. In each of these series of three rations, one ration contained fish meal and no APF supplement. There was also one ration containing fish meal plus the APF supplement and the third one contained no fish meal but the APF supplement.

On the basis of these data the following conclusions seem justified.

1. When solvent-extracted rice bran replaced corn at the levels used in this trial, very satisfactory growth was obtained.
2. The solvent-extracted rice bran did not affect the firmness of fat.
3. The APF supplement significantly improved ($P \leq .01$) the rations containing fish meal.
4. All-vegetable rations containing the APF supplement were equivalent to those containing fish meal without the APF.

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SOME FEEDING AND MANAGEMENT FACTORS AFFECTING AGE AT PUBERTY AND RELATED PHENOMENA IN CHESTER WHITE AND POLAND CHINA GILTS

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MOST pigs on farms which follow a once-a-year farrowing system are produced by gilts. Such a practice is considered more economical than keeping older, larger sows to farrow year after year.

Information reported by Phillips and Zeller (1943), Squiers *et al.* (1949), Warnick *et al.* (1949 and 1951), and Robertson *et al.* (1951), indicates that most gilts reach puberty between 6 and 8 months of age.

Since gilts must be bred at about 8 months of age in order to farrow at a year of age, many gilts must be bred soon after puberty, possibly at their first or second heat period. Warnick *et al.* (1951), and Robertson *et al.* (1951), reported that ovulation rates tend to increase rapidly with successive heat periods at least through the third period. Thus, those gilts which are bred at an early heat period would probably farrow fewer pigs than those gilts bred at later periods due, in part, to a lower ovulation rate in the early-bred gilts.

The present study is an attempt to determine the influence of (1) breed, (2) pasture, (3) percentage of protein in the ration, and (4) amount of feed offered the animals on: age and weight at puberty, ovulation rates at first and second heat periods, fertilization rates at second heat, and embryonic death during the first twenty-five days of gestation in Chester White and Poland China gilts.

Materials and Methods

An experiment of factorial design was used to study the effect of these four factors upon the various puberty phenomena in gilts.

Forty-eight Chester White and forty-eight Poland China outbred weanling gilts from the 1950 spring pig crop of the University of Wisconsin swine herd were used in this study. Animals for the experiment were chosen at random with the restriction that those gilts weighing less than twenty pounds when weaned at fifty-six days of age or those that lost weight from fifty-six to seventy days of age were not used. The

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gilts of each breed were assigned at random to the different feeding lots so that there were six gilts of each breed in each lot.

All gilts used in this study were farrowed during a twenty-seven day farrowing season (April 8-May 4). Each gilt was started on the experiment as she became seventy days of age.

Gilts were checked for heat once daily with a vasectomized teaser boar beginning September 9. This was thirty-one days prior to the first observed heat period. Two gilts (one Chester White in lot 2 and one Poland China in lot 6) had not exhibited estrus by the 250th day of age when the experiment was terminated, and they were slaughtered at that time. For purposes of analysis, age at puberty in these two gilts was considered to be 250 days.

Pasture consisted of a mixture of red clover, ladino clover, and brome grass. All pasture lots were clipped early in the experiment to

TABLE 1. RATIONS USED IN THIS STUDY

Ingredients	20% protein	15% protein	11.25% protein
Ground corn	480	565	610
Ground oats	240	285	340
Soybean meal (43%)	130	70	20.0
Tankage (50%)	140	70	20.0
Ground limestone	6.5	6.5	6.5
Salt	5.0	5.0	5.0

give the pigs the benefit of the new growth. Abundant pasture was available until the middle of October.

Dry lots were plowed prior to the beginning of the experiment and were disked again three weeks later to keep down vegetative growth. An electric fence (single strand—10 inches from the ground) was used very effectively in keeping the pigs away from the fence-rows which could not be kept free of vegetation.

High-protein lots were started on a 20% protein ration, and each lot was changed to a 15% protein ration when the pigs in the lot averaged 125 pounds in weight. Similarly, the low-protein lots were started on a 15% protein ration and were changed to a 11.25% protein ration at 125 pounds. The content of these rations is shown in table 1.

Pigs in full-fed lots, during the initial two-week period, were allowed all the feed they would consume twice daily. Later, after there were several pigs in each lot, self feeders were placed in the lots and feed was available at all times.

The limited-fed pigs which were on experiment during the initial

two-week period were allowed feed to the extent of 4% of their body weight. It was intended to have each limited-fed lot consume about two-thirds as much feed as its corresponding full-fed lot (animals treated similarly in all respects except amount of feed) during the course of the experiment, so, during the second and subsequent two-week periods, the limited-fed lots were allowed 70% of the amount of feed consumed by the corresponding full-fed lots during the previous two-week period. Later in the experiment, it became necessary to increase this figure to 80% due to the rapidly increasing feed consumption in the full-fed lots. Still later, as the full-fed lots tended to level off in feed consumption, the figure again was reduced to 70%.

Early in the experiment, three gilts of each breed in each of the eight feeding lots were randomly designated to provide information on ovulation rates at first and second heat periods and fertilization rates at second heat period (these gilts are hereafter referred to as "3-day" gilts). This information was obtained by breeding the gilts on the first day of their second heat and slaughtering 24–48 hours after the end of the heat period. Corpora lutea counts for both heat periods were made at that time, and fertilization rates were determined on eggs recovered by flushing the oviducts or uterine horns with a physiological salt solution. Presence of two or more blastomeres was the criterion of fertilization.

The remaining three gilts of each breed in each lot were also bred on the first day of their second heat but were slaughtered 25 days after mating. The number of corpora lutea from second heat and the number, size (crown-rump length), and normality of embryos was determined 30 minutes to an hour after slaughter. An embryo was considered normal if the heart beat could be observed, or if, in the absence of an observed heart beat, the embryo was of normal size and showed no signs of degeneration. Of the 309 normal embryos, heart beats were observed in 302 (97.4%). Five of the remaining seven embryos had fresh blood in the amniotic vesicle, possibly indicating they had been injured during the slaughtering process.

Six 25-day gilts (three Chester Whites and three Poland Chinas) which returned to heat prior to the 25th day were slaughtered for examination after coming into heat.

Twelve boars (six Chester Whites and six Poland Chinas) were mated to the gilts in this study. Each boar was mated to one gilt in each lot. The boar to be mated to a particular gilt was chosen at random, with the following restrictions: within each lot one 3-day gilt and one 25-day gilt of each breed were bred to a boar of the other

breed; the remaining gilts in the lot were all bred to boars of their own breed. This was done so that the effect of crossbreeding on fertility and early embryonic death might be studied.

Results of the study were examined statistically by an over-all analysis of variance of the data for the various puberty and reproductive phenomena. The mean square within breed-treatment groups was used as the error term in testing for over-all effects unless the factor under test was involved in a significant interaction, in which case the interaction mean square was used. "One-way comparisons", i.e., comparisons of the effects of the two levels of each of the four main factors within the same combination of the remaining factors, were made by using the least significant differences at the 5% and 1% levels of probability.

Results

General observations

Age and Weight at Puberty. Age at puberty for individual gilts ranged from 167 days to more than 250 days with a mean of 201 days and a gross standard deviation of 13.2 days (table 2). The individual weights at puberty ranged from 120 to 305 pounds with a mean of 195 pounds and a gross standard deviation of 35 pounds. Weight at puberty was significantly more variable (coefficient of variation C. V.=18.0%) than age at puberty (C. V.=6.6%).

Rate of Growth and Age at Puberty. Faster growing gilts tended to reach puberty earlier than slower growing gilts as shown by the highly significant negative correlation (—0.29) between weight at 154 days and age at puberty. Between- and within-group correlations were —.55 ($P \leqq 0.05$) and —0.12, respectively. It might be anticipated from these correlations that differences in growth rate due to treatment (breed and feeding) had more effect on age at puberty than individual differences in growth rate within the groups. It is not definitely shown, however, for the correlations are not significantly different.

Season of Farrow and Age at Puberty. Gilts which were farrowed later in the spring farrowing season tended to reach puberty at an earlier age as shown by the highly significant negative correlation between date of birth in the farrowing season and age at puberty. This over-all correlation was —0.63, with the between- and within-group correlation being —0.71 and —0.62, respectively.

Length of First Estrual Cycle. The length of the first estrual cycle in Chester White gilts ranged from 17 to 26 days with a mean of 20.2

TABLE 2. AVERAGE AGES AND WEIGHTS AT PUBERTY OF GILTS, BY BREED-TREATMENT GROUPS[1]

		Pasture				Dry-lot			
		high protein		low protein		high protein		low protein	
Breed	Phenomenon	full fed	limited fed	full fed	limited fed	full fed	limited fed	full fed	limited fed
Chester White	Age at Puberty	208	218	197	196	202	204	198	204
	Weight at Puberty	232	197	240	167	205	159	225	172
Poland China	Age at Puberty	194	198	192	193	201	209	196	206
	Weight at Puberty	215	191	212	191	165	159	211	176

	Age	Weight
Grand Mean	201 days	195 pounds
Gross Standard Deviation	13.2 "	35.0 "
Coefficient of Variation	6.6 %	18.0 %
5% L. S. D.[2]	14 days	29 pounds
1% L. S. D.	19 "	39 "

[1] All averages based on six gilts.
[2] Least significant difference.

days and a gross standard deviation of 1.52 days as compared to a range of 19 to 23 days with a mean of 20.8 days and a gross standard deviation of 0.87 days for the Poland China gilts. The difference between the average length of cycle for the two breeds was not significant, but the difference in variability was highly significant. This observation is in accord with a previous comparison of these two breeds at this station (Robertson *et al.* (1951)).

Ovulation Rates. Ovulation rates at first heat averaged 9.8 eggs per gilt for 46 of the 3-day gilts (table 3). (One Chester White and one Poland China did not reach puberty before the experiment terminated.) Information on ovulation rates at second estrus was provided by ninety gilts and the over-all average was 11.8 eggs per gilt. Forty-five of these gilts were the same as those which provided information on ovulation rate at first heat; the average ovulation rate at second heat for these gilts was the same as for the whole group. (In addition to the two gilts which did not attain puberty, ovulation rates were not available on three other gilts which had severe bilateral bursitis and salpingitis, and on one gilt which had no apparent second estrus.)

The over-all increase in ovulation rate from first to second estrus in the 3-day gilts was highly significant and averaged two eggs per gilt. The correlation between age at puberty and ovulation rate at second heat was 0.19 ($d/f=88$; $P>0.05$) with the between- and within-group correlations being 0.22 and 0.21. The correlation of weight at puberty and ovulation rate at second heat was highly significant, $r=0.36$, and this over-all correlation resolved itself into a between-group of 0.40 and a within-group of 0.34.

Fertilization Rates. None of the treatments in this study had a significant effect on fertilization rate, nor was there any clear evidence of a difference in fertility between the gilts bred to boars of the same breed, the "straight-bred", and gilts bred to boars of the other breed, "cross-bred", (95% vs. 92%). The over-all unweighted mean fertility was 93 percent.

Normal Embryos at 25 Days. Forty-five 25-day gilts provided information on the embryos at 25 days (table 4). The over-all unweighted average number of normal embryos was 6.7, representing approximately 55% of the number of corpora lutea present in the ovary at the time of slaughter. Thirty-six 25-day gilts were pregnant when slaughtered and provided information on size of embryos. The over-all average size of embryos at this stage of pregnancy was 16.9 mm. Type of mating, i.e. "straight-bred" vs. "cross-bred", had no apparent effect on number or size of embryos.

TABLE 3. OVULATION RATES IN GILTS

Breed	Phenomenon	Treatment Combinations: Pasture, high protein, full fed	Pasture, high protein, limited fed	Pasture, low protein, full fed	Pasture, low protein, limited fed	Dry-lot, high protein, full fed	Dry-lot, high protein, limited fed	Dry-lot, low protein, full fed	Dry-lot, low protein, limited fed
Chester White	Ovulation Rate 1st Heat	11.7	8.5[1]	11.7	8.3	11.3	8.0	12.0	10.3
	Ovulation Rate 2nd Heat	13.2	13.4[2]	13.0[2]	12.3	14.8[2]	11.3	15.7	14.5
	Increase 2nd—1st[3]	1.7	1.0[4]	1.3	5.3	4.0[4]	2.7	3.7	3.7
Poland China	Ovulation Rate 1st Heat	10.0	10.7	8.3	7.7	9.7	9.5[1]	10.7	8.3
	Ovulation Rate 2nd Heat	11.3	10.0	10.2	10.2	10.0[2]	8.8[2]	10.8[2]	9.8
	Increase 2nd—1st[3]	1.0	0.3	2.3	1.7	0.0	—0.5[4]	1.0	2.0

	First Heat (N=46)	Second Heat (N=90)	Increase 2nd—1st (N=45)
Grand Mean	9.8	11.8	2.0
Gross Standard Deviation	2.06	2.86	2.5
5% L. S. D.	1.5	1.9	4.2
1% L. S. D.	2.0	2.5	5.7

[1] Average based on 2 animals—all other values for 1st heat based on 3 animals.
[2] Average based on 5 animals—all other values for 2nd heat based on 6 animals.
[3] Average increase in ovulation rate from 1st to 2nd heat; values based on information from the 3-day gilts.
[4] Average based on 2 animals—all other values for increase in ovulation rate based on 3 animals.

TABLE 4. NUMBER, PERCENTAGE AND SIZE OF NORMAL EMBRYOS AT 25 DAYS[1]

Breed	Phenomenon	Pasture				Dry-lot			
		high protein		low protein		high protein		low protein	
		full fed	limited fed	full fed	limited fed	full fed	limited fed	full fed	limited fed
Chester White	Number of Embryos	5.7	13.0	4.0[3]	4.0	6.3	8.0	9.7	10.3
	% of Embryos[1]	41	82	27[3]	35	44	61	59	69
	Size (mm)	16.6[4]	17.9	16.8[5]	18.0[4]	17.6[4]	18.2[4]	17.8	17.8
Poland China	Number of Embryos	5.0	8.7	3.7	9.0	7.0[3]	7.7	3.5[3]	2.3
	% of Embryos[1]	34	97	37	82	66[3]	89	32[3]	21
	Size (mm)	17.2[4]	17.1	16.1[4]	16.4	16.8[4]	17.7	16.4[5]	12.1[4]

	Number	Per cent	Size
Grand Mean	6.7	55	16.9
Gross Standard Deviation	4.5	34	1.53
5% L. S. D.	7.2	52	2.0
1% L. S. D.	9.8	69	2.7

[1] All values in this table are unweighted Lot means and based on 3 gilts, except as noted.

[2] $\%\ \text{Normal embryos at 25 days} = \frac{\text{No. Normal embryos at 25 days}}{\text{No. Corpora Lutea at 25 days}} \times 100.$

[3] These means are based on two gilts (three gilts were not included because of bilateral bursitis and salpingitis).

[4] These values based on two gilts.

[5] These values based on one gilt.

Breed Effects

The effects of breed are indicated by the values for the Chester White minus the values for the Poland China (table 5).

Age at Puberty. The Chester Whites were significantly older than the Poland Chinas at the time of puberty in the pasture, high-protein groups both full fed and limited fed. Significant differences did not occur in any of the other treatment groups. Analysis of variance, however, did show a significant interaction between breed and pasture. This can be seen by the fact that the differences between the Chester White and Poland China ranged from 3 to 20 days in the pasture groups, whereas they ranged from 2 to —5 days in the dry-lot groups.

Weight at Puberty. A significant breed effect upon weight at puberty was found only in the dry-lot, high-protein, full-fed groups. Here the Chester Whites were 40 pounds heavier at puberty than the Poland Chinas. Analysis of variance showed a significant interaction of feeding level with breed. This is readily seen from the greater differences in weight in favor of the Chester Whites in the different full-fed groups as contrasted to their limited-fed opposites, i.e., 17 as contrasted to 6 in the pasture, high-protein groups; 28 as contrasted to —24 in the pasture, low-protein; 40 as compared to 0 in the dry-lot, high-protein; and 14 compared to —4 in the dry-lot, low-protein groups.

Ovulation Rate at First Heat. The analysis of variance did not show an over-all significant breed difference in ovulation rate at first heat. Chester White gilts ovulated a significantly greater number of eggs than the Poland Chinas in four of the lots; namely, both pasture full-fed lots, the dry-lot, high-protein, full-fed lot, and the dry-lot, low-protein, limited-fed lot. However, in both of the high-protein, limited-fed lots the Poland Chinas had a significantly higher ovulation rate at first heat than the Chester Whites. Analysis of variance showed a significant interaction of feeding level with breed. In three of four comparisons of a full-fed lot with its corresponding limited-fed lot, the difference in ovulation rate is in favor of the Chester White in the full-fed lot, and either very small or in favor of the Poland Chinas in the limited-fed lot. In the fourth comparison of full-fed with limited-fed (within dry-lot, low-protein) the breed difference in ovulation rate is of about the same magnitude and in favor of the Chester Whites in both cases.

Ovulation Rate at Second Heat. Chester White gilts ovulated a significantly greater number of eggs at second heat in all treatment lots than the Poland Chinas. The over-all breed difference was highly

TABLE 5. BREED EFFECTS—CHESTER WHITE MINUS POLAND CHINA

Treatment Group			Age at Puberty	Weight at Puberty	Ovulation Rate			Normal Embryos at 25 Days		
					First Heat	Second Heat	Second-first	Number	%	Size (mm)
P[1]	HP	FF	14*	17	1.7*	1.9*	0.7	0.7	7	—0.6
P	HP	LF	20**	6	—2.2**	3.4**	0.7	4.3	—15	0.8
P	LP	FF	5	28	3.4**	2.8**	—1.0	0.3	—10	0.7
P	LP	LF	3	—24	0.6	2.1*	3.6	—5.0	—47	1.6
DL	HP	FF	1	40**	1.6*	4.8**	4.0	—0.7	—22	0.8
DL	HP	LF	—5	0	—1.5*	2.5**	3.2	0.3	—28	0.5
DL	LP	FF	2	14	1.3	4.9**	2.7	6.2	27	1.4
DL	LP	LF	—2	—4	2.0**	4.7**	1.7	8.0*	48	5.7**
Over All Treatments			5	10	0.8	3.4**	1.9*	1.7	—5.0	1.4**

* $P \leq 0.05$
** $P \leq 0.01$
[1] P=Pasture
HP=High-protein
FF=Full-fed
DL=Dry-lot
LP=Low-protein
LF=Limited-fed

significant. There were no significant interactions of breed with treatment factors.

Increase in Ovulation Rate. Chester White gilts increased in ovulation rate from first to second heat more than the Poland Chinas in seven of the eight feeding lots. Though the difference was not significant in any one lot, the over-all difference was significant ($P \leqq 0.05$). There were no evident interactions of breed with any of the treatment factors.

Number of Normal Embryos. There was a significant breed influence on number of embryos in the dry-lot, low-protein, limited-fed lot. Here the Chester Whites averaged 8 more embryos at 25 days than the Poland Chinas ($P \leqq 0.05$). Analysis of variance showed a significant interaction of breed with pasture and level of protein. This can be seen by comparing the average for high-protein with the average for low-protein within the pasture lots and noting that the relationship is reversed when a similar comparison is made in the dry-lots.

Percentage of Normal Embryos. There were no clear breed differences in normal embryos at 25 days of gestation expressed as a percentage of number of corpora lutea present. Analysis of variance, however, again showed a significant three-factor interaction of breed with pasture and level of protein as indicated above for number of embryos.

Size of Embryos. Size of embryos in the Chester White gilts was significantly greater than in the Poland China gilts in the dry-lot, low-protein, limited-fed lot. Here there was an average difference of 5.7 mm ($P \leqq 0.01$). The greater size of embryos from Chester White gilts in other lots was so consistent that the over-all breed difference of 1.4 mm (17.6 vs. 16.2) in favor of the Chester Whites was also highly significant.

Embryos from Chester White gilts bred to Poland China boars averaged 17.5 mm and those from Poland China gilts bred to Chester White boars averaged 16.1 mm, a difference of 1.4 mm. A similar difference (1.2 mm) between the size of the "straight-bred" Chester White embryos and the "straight-bred" Poland China embryos indicates that maternal effects, or cytoplasmic, or possibly sex-linked factors are playing a role in determining embryo size.

Effects of Pasture

The effects of pasture are shown by comparisons of pasture values minus dry-lot values within the eight combinations of the two levels of feeding, two levels of protein, and two breeds (table 6).

TABLE 6. EFFECT OF PASTURE—PASTURE MINUS DRY-LOT

Breed—Treatment Group			Age at Puberty	Weight at Puberty	Ovulation Rate			Normal Embryos at 25 Days		
					First Heat	Second Heat	Second-first	Number	%	Size (mm)
HP	FF	CW	6	27	0.4	—1.6	—2.3	—0.6	—3.0	—1.0
HP	FF	PC	—7	50**	0.3	1.3	1.0	—2.0	—32.0	0.4
HP	LF	CW	14*	38*	0.5	2.1*	—1.7	5.0	21.0	—0.3
HP	LF	PC	—11	32*	1.2	1.2	0.8	1.0	8.0	—0.6
LP	FF	CW	—1	15	—0.3	—2.7**	—2.4	—5.7	—32.0	—1.0
LP	FF	PC	—4	1	—2.4**	—0.6	1.3	0.2	5.0	—0.3
LP	LF	CW	—8	—5	—2.0**	—2.2*	1.6	—6.3	—34.0	0.2
LP	LF	PC	—13	15	—0.6	0.4	—0.3	6.7	61.0*	4.3**
Over All Groups			—2	22	—0.4	—0.3	—0.3	—0.2	—1.0	0.2

* $P \leqq 0.05$
** $P \leqq 0.01$

Age at Puberty. The only comparison between pasture and dry-lot which showed significantly different results in age at puberty was in the high-protein, limited-fed Chester White group. Here the pasture group averaged 14 days older at puberty than the dry-lot group. The significant interaction between pasture and breed, discussed earlier, is indicated here in the column for age at puberty by comparisons of 6 with −7, 14 with −11, −1 with −4, and −8 with −13.

Weight at Puberty. Significantly heavier weights at puberty were found for the Poland Chinas on the high-protein, full-fed treatment and for both breeds on the high-protein, limited-fed treatment. Further than this, a significant interaction between protein level and pasture is seen in the fact that the pasture lots averaged heavier by 27 to 50 pounds in the high-protein group, whereas they were heavier by −5 to 15 pounds in the low-protein group.

Ovulation Rate at First Heat. The full-fed, low-protein Poland Chinas and the limited-fed, low-protein Chester White gilts ovulated a significantly greater number of eggs at first heat on pasture than in dry-lot. The over-all difference in ovulation rate at first heat between pasture and dry-lot was not significant, nor were there any significant interactions of pasture with other factors. However, the differences are consistently in favor of pasture in the high-protein lots and in favor of dry-lot in the low-protein lots. These trends constitute an interaction between pasture and level of protein which approached the 5% level of significance.

Ovulation Rate at Second Heat. Significant differences in ovulation rate at second heat were observed in three groups of Chester White gilts; namely, the high-protein, limited-fed (in favor of pasture), and the low-protein, both full- and limited-fed groups (in favor of dry-lot). A significant pasture-level of protein interaction can be seen by comparing the values for each high-protein lot with the comparable low-protein lot. In each case the value for the high-protein lot is higher than the value for the low-protein lot.

Increase in Ovulation Rate. There were no significant effects of pasture on the increase in ovulation rate from first to second heat, nor were there any interactions of pasture with other factors studied.

Number of Normal Embryos. A three-factor interaction of pasture, breed, and level of protein is observed in the number of embryos. This interaction was mentioned above under breed effects. It will be observed that within the high-protein groups, the values for the Chester Whites are larger than the values for the Poland Chinas, whereas, in

the low-protein groups they are smaller than the values for the Poland Chinas.

Percentage of Normal Embryos. Pasture effects on percentage of corpora lutea represented by normal embryos at 25 days were significant in only the low-protein, limited-fed Poland China group. In this group the gilts on pasture had a greater percentage of normal embryos than those in dry-lot ($P \leqq 0.05$). A significant interaction of pasture with breed and level of protein (mentioned above under breed effects) is readily seen here in that, in the high-protein groups, the values for Chester Whites exceed those for the comparable Poland Chinas, whereas in the low-protein groups, the values for the Chester Whites are less than those for the Poland Chinas.

Size of Embryos. The effects of pasture on embryo size were significant in only the low-protein, limited-fed Poland China group. The average size of embryo in this group was 4.3 mm larger in gilts on pasture than in gilts in dry-lot. There was a significant three-factor interaction of pasture with level of protein and level of feeding which can be seen by comparing values for full-fed groups with the values for limited-fed groups within high- and low-protein. It will be observed that within the high-protein groups the average value for the full-fed lots is slightly greater than the average value for the limited-fed lots, whereas within the low-protein groups the average of the full-fed animals is much less than the average value for the limited-fed animals.

Effects of Level of Feeding

Age at Puberty. The differences in age at puberty between the full-fed and limited-fed groups were not significant in any case (table 7), nor were there any significant interactions of the other factors with the level of feeding. The over-all advantage of full- over limited-feeding approached the 5% level of significance.

Weight at Puberty. The full-fed animals were heavier at the time of puberty in all of the Chester White groups (by 35, 73, 46 and 53 pounds). Only the dry-lot, low-protein treatment for the Poland Chinas showed a significantly heavier weight for the full-fed group. The significant interaction between level of feeding and breed, which was mentioned earlier, can be seen here in the fact that the Chester Whites exceeded the Poland Chinas in the effects of full-feeding in each of the four comparisons (35 vs. 24; 73 vs. 21; 46 vs. 6; and 53 vs. 35). Full-fed Chester Whites were significantly heavier at puberty than full-fed Poland Chinas. The analysis of the data within breeds showed a

TABLE 7, EFFECTS OF LEVEL OF FEEDING—FULL-FED MINUS LIMITED FED

Breed—Treatment Group			Age at Puberty	Weight at Puberty	Ovulation Rate			Normal Embryos at 25 Days		
					First Heat	Second Heat	Second-first	Actual No.	%	Size (mm)
P	HP	CW	−10	35*	3.2**	−0.2	0.7	−7.3*	−41	−1.3
P	HP	PC	−4	24	−0.7	1.3	0.7	−3.7	−63*	0.1
P	LP	CW	1	73**	3.4**	0.7	−4.0	0.0	−8	−1.2
P	LP	PC	−1	21	0.6	0.0	0.6	−5.3	−45	−0.3
DL	HP	CW	−2	46**	3.3**	3.5**	1.3	−1.7	−17	−0.6
DL	HP	PC	−8	6	0.2	1.2	0.5	−0.7	−23	−0.9
DL	LP	CW	−6	53**	1.7*	1.2	0.0	−0.6	−10	0.0
DL	LP	PC	−10	35*	2.4**	1.0	−1.0	1.2	11	4.3**
Over All Groups			−5	37	1.8	1.1*	−0.1	−2.3	−25*	0.0

* $P \leqq 0.05$
** $P \leqq 0.01$

significant difference between full- and limited-fed gilts in each case. The effect thus appears to be general but less in the Poland China than in the Chester White.

Ovulation Rate at First Heat. Full-fed gilts ovulated more eggs at first heat in seven of the eight groups. The difference in favor of the full-fed animals was significant in all groups of Chester White gilts but in only one Poland China group, namely, the dry-lot, low-protein group. The significant interaction of breed with level of feeding (mentioned under breed effects) is seen by comparing the values for the Chester White with those of the Poland China. In three of four such comparisons the values for the Chester Whites are much greater than those for the Poland Chinas (3.2 vs. —0.7; 3.4 vs. 0.6; 3.3 vs. 0.2), whereas in the remaining case the difference is small and in favor of the Poland Chinas (1.7 vs. 2.4).

Ovulation Rate at Second Heat. The advantage of full-feeding over limited-feeding in ovulation rate at second heat is significant in only one case, i.e., the dry-lot, high-protein Chester White group. However, the differences in the seven remaining groups are such that the over-all advantage of full-feeding over limited-feeding is significant ($P \leqq 0.05$). There were no evident interactions of level of feeding with other factors.

Increasing Ovulation Rate. Level of feeding apparently had no effect on rate of increase in ovulation rate from first to second heat, either as a direct effect or in interaction with other factors.

Number of Normal Embryos. Limited-fed gilts had a significantly higher number of normal embryos than the full-fed gilts in the pasture, high-protein Chester White group. The over-all difference was not significant, nor were there any significant interactions of level of feeding with other factors.

Percentage of Normal Embryos. Limited-fed gilts had a higher percentage of their corpora lutea represented by normal embryos at 25 days in all but one of the eight comparisons. Within groups, the difference was significant only for the pasture, high-protein Poland China, but the over-all difference was significant.

Size of Embryos. Limited feeding resulted in significantly smaller embryos in the dry-lot, low-protein Poland China group. Over all lots there was no difference in size of embryos from full- and limited-fed gilts. There was an interaction, which was mentioned earlier, between level of feeding and pasture and level of protein. There is little difference between the average values for high- and low-protein on pasture, but in the dry-lots the values for low-protein are much higher than the values for high protein.

Effects of Level of Protein

Age at Puberty. High-protein increased age at puberty significantly over low-protein in one specific group, namely, the pasture, limited-fed Chester White (table 8). In addition to this, the increases in the other groups were consistent enough that analysis of variance showed a significant general protein effect on age with no complicating interactions evident.

Weight at Puberty. The effects of protein level on weight at puberty were significant in the pasture, limited-fed Chester White group and in the dry-lot full-fed Poland China group. In the first case the high-protein exceeded the low-protein in weight at puberty by 30 pounds, but in the other case, the low- exceeded the high-protein by 46 pounds. The significant interaction between pasture and protein level, pointed out above, can be seen in this instance by the fact that in the pasture group the high-protein advantage in weight at puberty ranges from —8 to 30 pounds, whereas, in the dry-lot group the advantage is in favor of the low-protein by 13 to 46 pounds.

Ovulation Rate at First Heat. Ovulation rate at first heat in the Poland China gilts on pasture, whether full- or limited-fed, was increased by the high protein. However, in the limited-fed Chester White gilts in dry-lot, the low-protein ration produced a significantly higher ovulation rate at first heat. Over-all effects of protein level and interactions with other factors were not significant. However, the pasture-level of protein interaction which approached significance, as mentioned earlier, can be seen here by comparing the pasture values with the comparable dry-lot values. In each case the pasture values are greater than the dry-lot values.

Ovulation Rate at Second Heat. In the dry lot, limited fed Chester White group, ovulation rate at second heat was significantly lower on high- than on low-protein. Analysis of variance showed no over-all significant difference between high- and low-protein. The significant interaction between level of protein and pasture, which was pointed out earlier under pasture effects, is evident here, in that the values for the pasture group range from —0.2 to 1.1, while the values for the dry-lot group range from —3.2 to —0.8.

Increase in Ovulation Rate. Increase in ovulation rate was affected significantly, as judged by the L.S.D., in only the pasture, limited-fed, Chester White group. Here the low-protein gilts showed a 4.3-egg greater increase than did the high-protein gilts. Over-all effects and interactions, however, were not significant.

TABLE 8. EFFECTS OF LEVEL OF PROTEIN—HIGH-PROTEIN MINUS LOW-PROTEIN

Breed—Treatment Group			Age at Puberty	Weight at Puberty	Ovulation Rate			Normal Embryos at 25 Days		
					First Heat	Second Heat	Increase Second-first	Actual No.	%	Size (mm)
P	FF	CW	11	—8	0.0	0.2	0.4	1.7	14	—0.2
P	FF	PC	2	3	1.7*	1.1	—1.3	1.3	—3	1.1
P	LF	CW	22**	30*	0.2	1.1	—4.3*	9.0*	47	—0.1
P	LF	PC	5	0	3.0**	—0.2	—1.4	—0.3	15	0.7
DL	FF	CW	4	—20	—0.7	—0.9	0.3	—3.4	—15	—0.2
DL	FF	PC	5	—46**	—1.0	—0.8	—1.0	3.5	34	0.4
DL	LF	CW	0	—13	—2.3**	—3.2**	—1.0	—2.3	—8	0.4
DL	LF	PC	3	—17	1.2	—1.0	—2.5	5.4	68*	5.6**
Over All Groups			6*	—9	0.2	—0.5	—1.3	1.9	19	1.0

* $P \leqq 0.05$
** $P \leqq 0.01$

Number of Normal Embryos. High protein resulted in a significantly larger number of normal embryos at 25 days in the pasture, limited-fed, Chester White group. There was a significant three-factor interaction of level of protein with breed and pasture (mentioned previously) which is seen in this instance by comparing values for the two breeds within pasture and dry-lot groups. The Chester White values are greater than the Poland China values within the pasture groups (1.7 vs. 1.3; 9.0 vs. —0.3) but in the dry-lots the Poland China values are greater (—3.4 vs. 3.5; —2.3 vs. 5.4).

Percentage of Normal Embryos. The advantage of a high-protein ration over a low-protein ration in percentage of corpora lutea accounted for by normal embryos was significant in the dry-lot, limited-fed Poland China group. The significant interaction of level of protein with pasture and breed, which was mentioned earlier, is seen here by comparing the values for the two breeds within the pasture and dry lot groups. In the pasture lots the Chester White values are higher than the Poland China values (14 vs. —3; 47 vs. 15), whereas, in the dry lots the situation is reversed so that the Poland China values are higher than the Chester White (—15 vs. 34; —8 vs. 68).

Size of Embryos. The advantage of high-protein over low-protein in producing larger embryos at 25 days was highly significant in one specific group (dry-lot, limited-fed, Poland China). Further, the significant interaction of level of protein with pasture and level of feeding, which was mentioned previously, appears here as a greater difference between the comparable limited-fed and full-fed groups in dry lot than on pasture.

Discussion

McKenzie (1928) reported that gilts which received 41–48 percent of a full ration were not only retarded in body growth but also in the development of the genital organs so that some did not come into heat until nearly one year of age. Asdell and Crowell (1935) found that vaginal opening in young rats could be delayed by limiting caloric intake and thus reducing the rate of growth. Engle *et al.* (1937) reported that female rats from smaller litters reached puberty earlier than those from larger litters. They believed that the difference in age at puberty resulted from a difference in growth rate. Blunn (1939) found differences in age at puberty between two strains of rats which were reared under similar environmental conditions; the faster growing strain reached puberty earlier than the slow growing strain. He noted that

there was less variability in age at puberty than in weight at puberty. He concluded that, "For the rats studied, genetic composition is of more importance in determining the age at which the animals become sexually mature than is the size of the litter raised to weaning time." He further concluded that though there was an association between rapid rate of growth and early maturity, they were separable phenomena.

Evidence that age at maturity in swine is affected both by genetic constitution and by environmental factors which affect the rate of growth was reported by Warnick *et al.* (1951). They reported that the faster growing gilts within lines tended to reach puberty at an earlier age than the slower growing gilts, but that the faster gaining lines tended to be slower in reaching puberty. In the present study the heavier groups of gilts at 154 days of age tended to reach puberty earlier than those which weighed less at that time. Attainment of puberty in the gilts in the limited fed lots of this study apparently was not delayed to the same extent as in those reported on by McKenzie (1928). It should be pointed out, however, that the retardation of puberty in swine (McKenzie) and in rats (Asdell and Crowell) resulted from a more severe restriction of feed intake than was true in this study.

The negative association between birth date in the spring farrowing season and age at puberty of these gilts is in accord with earlier work at this station reported by Wiggins *et al.* (1950) and by Robertson *et al.* (1951). In another study, however, Warnick *et al.* (1951) reported that the correlation between date of farrow and age at puberty within inbred lines of swine during the 1949 season was positive. They suggested that outbreaks of disease might have acted directly or affected gain in body weight in such a way as to mask the effect of season of birth which would ordinarily be expressed. In the present study, however, where wide differences in rate of gain between treatment groups were induced by different feeding regimes, rather than by disease conditions, the negative association between date of farrow and age at puberty was found. This indicates that the variable health conditions in the inbred herd might have exerted an influence on age at puberty through some medium other than body weight, or that a decrease in rate of gain due to disease was more effective in masking the seasonal influence on age at puberty than a similar decrease which resulted from restricted feed intake.

While attainment of puberty usually tends to be associated with rate of growth, it is possible that it is not rate of growth in itself which affects age at puberty. Perhaps certain other factors have a direct influence on the sexual development of the animal and have a con-

current effect on rate of growth. In this experiment, level of protein in the ration was the only treatment factor studied which had a significant over-all effect on age at puberty. Gilts receiving the low protein ration were 13 pounds heavier at 154 days and reached puberty 6 days earlier than those receiving the high protein ration. The retarding effect of the high protein ration on sexual maturity is in accord with the work of Aschkenasy-Lelu *et al.* who reported in 1947 (according to Russell, 1948) that an excess of protein in the ration of young female rats delayed somatic and sexual development. Among the limited fed Chester White gilts on pasture, the high protein ration appeared to delay the onset of puberty through some medium other than an effect on rate of gain, since the high protein gilts were 30 pounds heavier but 22 days older than the low protein gilts. Further, the retarding effect of the high protein ration appeared to be of greater importance in the Chester White gilts than in the Poland China gilts when both are reared under pasture conditions. Within the pasture lots, among those gilts receiving the high protein ration, the Chester Whites were significantly older at puberty than were the Poland Chinas; whereas, among those receiving the low protein ration, there was not a significant breed difference in age at puberty.

There appears to be a generally consistent advantage of high protein over low protein in the pasture lots, and of low protein over high protein in the dry lots with respect to (1) weight at puberty, (2) ovulation rate at first heat, and (3) ovulation rate at second heat. High protein gilts were 5 pounds heavier at puberty than low protein gilts on pasture, but were 24 pounds lighter in the dry lots. Further than this the high protein ration on pasture tended to favor higher ovulation rates at second heat than did the low-protein ration (12.0 vs. 11.4) whereas in the dry-lots the low-protein ration was accompanied by higher ovulation rates (12.7 vs. 11.2). A similar interaction occurred at first ovulation ($P \cong 0.07$) which was consistent in direction with that at second ovulation. The only other one of the reproductive phenomena affected significantly by this interaction of pasture and level of protein was age at puberty in the Chester White gilts. The high-protein gilts averaged 17 days older than low-protein gilts on pasture but only 2 days older in dry-lot.

Full-feeding resulted in significantly heavier weights at puberty within each breed and also in higher ovulation rates at second heat (when both breeds are considered together) than did limited-feeding. Full-fed gilts also ovulated more eggs at first heat than did limited-fed

gilts (10.7 vs. 8.9) but this over-all difference was not significant. Full-fed Chester Whites ovulated 2.9 eggs more at first heat than did limited-fed Chester Whites ($P \leqq 0.01$) whereas, among the Poland China gilts the advantage of full-feeding over limited-feeding was only 0.7 egg and not consistent in the different groups. At each heat period the slower growing gilts tended to have the lower ovulation rates whether the variation in growth rate was due to the treatment of the group or to the individuality of the gilt within the treatment group.

It is possible that the lower ovulation rates in the limited-fed gilts resulted from a low level of pituitary gonadotrophic secretion. Such a hypothesis is supported by the work of Mason and Wolfe (1930) who reported that prolonged periods of underfeeding resulted in reduced gonadotrophic potency of the anterior pituitary of rats.

Fifty-five percent of the ova (corpora lutea in the ovaries at the time of slaughter) were represented by normal embryos at 25 days. Seven percent of the remaining ova were accounted for by an observed failure of fertilization. The difference between the percentage of ova accounted for, either by presence of normal embryos or by failure of fertilization, and 100% was assumed to be due to embryonic death, in this instance —38%. Embryonic death apparently was much higher in the full-fed than in the limited-fed gilts. Limited-fed gilts had 67% normal embryos at 25 days as compared to 43% for the full-fed gilts. The physiological basis for this difference ($P \leqq 0.05$) is not known. Hansen *et al.* (1950) reported a somewhat similar observation in a study with cattle where fetal atrophy becomes sterility rather than reduced fertility. They had three groups of Red Danish heifers which they fed on different planes (normal, poor, and heavy feeding) prior to putting them into the milking herd where all animals were fed according to the normal plan. At the time of their report, 30% of the cows in the poorly fed group had 7 or more calvings, while in the normally fed group and the heavily fed group comparable values were 21% and 7% respectively.

On the assumption that the above findings will be borne out by later work, the following evaluation of the effects of the various feeding and management practices on reproductive efficiency may be made.

The criterion of reproductive efficiency will be taken as the number of normal embryos in the uterus on the 25th day of gestation. This number is influenced by (a) the number of eggs ovulated, (b) the number of these eggs which is fertilized, and (c) the number of embryos which has died prior to the 25th day. Since there were no significant differences in fertilization rates between groups, this study resolved

itself into an evaluation of the effects of the various treatment combinations on ovulation rates and embryonic death rates.

The differences in ovulation rates due to the effects of pasture and level of protein in the ration are not large enough nor consistent enough to justify a recommendation as to their use. The data do indicate, however, that full-feeding of gilts from weaning age to time of mating would favor higher ovulation rates than limited-feeding. On the other hand, the data on percentage of embryos at 25 days indicate that limited-feeding is more conducive to embryo survival than full-feeding, but as far as the different levels of protein and pasture are concerned no over-all recommendation can be made due to the lack of consistency in the data. One possible exception to the recommendation of limited feeding would be the Poland China gilts in dry-lots on the low protein ration; the full-fed gilts in this group were superior but not significantly so.

Thus it appears that the two phenomena which are of greatest importance in determining the number of embryos at 25 days are not favored by exactly the same system of management. If the plan which resulted in higher ovulation rates was followed from weaning to time of mating and then replaced by the plan which favored the greatest percentage of embryos at 25 days, the end result might be still a greater number of embryos than was found when either system was used during the entire period to the exclusion of the other as was done in this study. However, it is possible that the first plan (especially since it would operate over a much longer period of time) might create an internal environment that would preclude any beneficial effects of the second system. Also the second plan might not have as much advantage in maintaining the embryos if it were delayed until mating.

Further investigations must be undertaken in different years and at other stations before the effects of these and other factors on reproductive phenomena can be considered established. Improvement of the reproductive efficiency of swine through the use of proper feeding and management practices might be attacked by determining first the optimum plan of management for each phase of the reproductive cycle; i.e., from birth to puberty, breeding season (with emphasis on ovulation rate), gestation (with emphasis on embryonic and fetal death rate), and lactation (particularly as it affects postnatal survival and growth).

After the best plan of management for each phase of the reproductive cycle has been established, there remains the problem of studying these plans in tandem to determine how they might be fitted together into

one over-all improved plan for the whole reproductive cycle. The extent to which harmful interactions and carry-over effects might complicate the problem and to what extent they could be overcome can only be determined by extensive investigations. Such a program must be carried out before a complete basis for practical recommendations can be arrived at.

Summary

An experiment of factorial design was used to study the effects of three variations of feeding and management upon various reproductive phenomena in 48 Chester White and 48 Poland China gilts.

The average age at puberty of gilts in this study was 201 days with a standard deviation of 13.2 days, while the average weight at puberty was 195 pounds with a standard deviation of 35 pounds. Age at puberty was less variable than weight at puberty, the coefficients of variation being 6.6% and 18.0%, respectively.

Gilts which were born later in the spring farrowing season tended to reach puberty at a younger age.

There was significantly greater variability in length of the first estrual cycle in the Chester White than in the Poland China gilts.

Full-fed gilts tended to reach puberty earlier than limited-fed gilts, and gilts which received the low protein ration were 6 days younger at first heat than those which received the high protein ration ($P \leqq 0.05$). There was not an over-all significant difference in age at puberty between the two breeds, but the Chester Whites were 11 days older than the Poland Chinas in the pasture lots ($P \leqq 0.01$) and 1 day younger in the dry lots. Poland China gilts were 9 days younger at puberty on pasture than in dry lot ($P \leqq 0.05$) while the Chester White gilts were 3 days older on pasture than in dry lot.

Full-fed gilts of each breed were significantly heavier at puberty than limited-fed gilts. Full-fed Chester White gilts were heavier than full-fed Poland Chinas ($P \leqq 0.01$). High protein fed gilts were 5 pounds heavier at puberty than low protein fed gilts on pasture, but were 24 pounds lighter in dry lot.

The average ovulation rate at first heat over all lots was 9.8 eggs per gilt. Full-fed Chester White gilts ovulated 2.9 more eggs at first heat than did limited-fed Chester Whites ($P \leqq 0.01$), whereas full-fed Poland China gilts exceeded the limited-fed Poland Chinas by only 0.7 egg. High-protein fed gilts tended to ovulate more eggs than low-protein fed gilts if on pasture, but fewer eggs if in dry-lot ($P \cong 0.07$).

At the second heat period, the average ovulation rate was 11.8 eggs per gilt, an average increase of two eggs per gilt over the ovulation rate at first heat ($P \leqq 0.01$). Full-fed gilts ovulated 1.1 eggs more per gilt than did limited-fed gilts, a difference which was significant over all lots. Also, Chester White gilts ovulated an average of 3.4 eggs per gilt more than Poland China gilts, a difference which was highly significant over all lots. Here again, the high-protein gilts ovulated more eggs than low-protein gilts on pasture but fewer eggs in dry-lots, and in this instance the interaction was significant.

The over-all unweighted mean fertility of ova in this study was 93%. There were no significant differences in fertilization rate between the breed-treatment groups. Nor was there any difference in fertility due to the breed of boar to which the gilts were mated.

The average number of normal embryos per gilt at 25 days was 6.7. These embryos represented approximately 55% of the ova ovulated at second heat. Of the remaining 45%, approximately 7% were accounted for by an observed failure of fertilization, leaving 38% which were lost presumably due to embryonic death. Limited-fed gilts tended to have more embryos at 25 days of gestation than the full-fed gilts. When compared on a percentage basis the difference was statistically significant over all lots, the limited-fed gilts having 67% of the corpora lutea of second heat represented by normal embryos while the full-fed animals had only 43% embryos. However, limited feeding of the low-protein ration to Poland China gilts in dry-lot resulted in a reduction of both number and size of embryos present at 25 days.

The over-all average size of embryos at the 25th day of pregnancy was 16.9 mm, with the embryos from the Chester White gilts averaging 17.6 mm as compared to 16.2 mm for those from the Poland China gilts ($P \leqq 0.01$).

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THE EFFECT OF PARTICLE SIZE AND PHOSPHOLIPID ON GROWTH AND FAT UTILIZATION OF THE BABY PIG[1]

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It is a common observation among swine producers that fewer digestive disturbances and generally better results are obtained in attempts to raise orphan pigs when skimmilk or cow's milk low in fat is fed. Holstein milk is generally recommended over that of other breeds.

Beach (1904) reported serious digestive disturbances and lower gains for pigs fed cow's milk rich in fat. He attributed these effects to excess of fat and to the character of the fat. Studies by Evvard *et al.* (1923–25) further substantiated the earlier observations regarding the adverse effects of milks rich in fat. Distribution of the fat and particle size was not considered in these early studies.

Gullickson's work with dairy calves (1942) has shown that in general when lactose was the source of carbohydrate, animal fats were superior to vegetable fats, even though the vegetable oils were homogenized before feeding. More recently Bate *et al.* (1946) reported a marked improvement in the nutritive value of soybean oil for young calves if the oil was homogenized prior to feeding. Shantz *et al.* (1940) found that the addition of 0.25 percent and 0.50 percent of egg lecithin to corn oil and coconut oil improved the nutritive value of these oils, when they were homogenized into mineralized skimmilk at a level of 4 percent and fed to weanling rats. The nutritive value of these oils thus dispersed did not, however, equal that of butterfat. Recently Kastelic *et al.* (1950) fed a "semisynthetic milk coagulable by rennet" to colostrum-free calves. They observed that the use of butter oil emulsified with soya lecithin in a Waring Blendor as a source of fat gave better growth than cottonseed oil similarly dispersed. However, an excellent response was obtained when cottonseed oil was thoroughly homogenized with an aqueous suspension of soya lecithin before it was added to the "milk". The proportion of phospholipid to fat was 400 grams lecithin to 10 pounds of cottonseed oil.

The study reported herein was made to ascertain the effect of

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[2] Animal Husbandry and Biochemistry Departments.

particle size and phospholipids on growth and fat absorption of baby pigs. The beneficial effects of colostrum feeding were also studied.

Experimental

Thirty grade Hampshire baby pigs from 5 different litters were used in this study. The experiment was divided into 2 trials and each trial into 2 groups: pigs which were left with the sow for a 2-day nursing

TABLE 1. EXPERIMENTAL DESIGN

Trial	Group	Litter farrowed	Lots (2 pigs)	Physical state of fat in the ration
1	Colostrum	10/1/50	IA	Less than 2 microns
			IIA	6 to 8 microns
			IIIA	Waring Blendor + phospholipids
		9/27/50	IVA	Waring Blendor, no phospholipids
	No colostrum	9/27/50	VA	Less than 2 microns
			VIA	6 to 8 microns
			VIIA	Waring Blendor + phospholipids
2	Colostrum	11/5/50	IB	Less than 2 microns
			IIB	6 to 8 microns
			IIIB	Waring Blendor + phospholipids
		11/18/50	IVB	Waring Blendor, no phospholipids
	No colostrum	11/2/50	VB	Less than 2 microns
			VIB	6 to 8 microns
			VIIB	Waring Blendor + phospholipids
		11/18/50	VIIIB	Waring Blendor, no phospholipids[1]

[1] Lot VIII added in trial 2 to further impose hardship for no-colostrum pigs.

period, and pigs which were put on experiment immediately after birth without the benefits of colostrum. The design of the experiment is summarized in table 1.

The pigs were kept in individual wire-bottom metabolism type cages. They were fed 3 times daily, the total daily feed intake for each group was determined by a paired feeding technique, that is, the daily feed intake per pig was adjusted to the lowest feed intake of any single pig in that group.

The ration used was a synthetic milk as previously described by Sheffy *et al.* (1951). B_{12} was fed at a level of 56 γ per kilogram of dry

matter. The antibiotics streptomycin and aureomycin were fed at a level of 250 mg. and 125 mg. per kilogram dry matter respectively. The level of fat was the same in all lots. The lard, however, was subjected to the following treatments prior to feeding: In order to reduce the size of the fat globules, a Gaulin single-action homogenizer was used in preparing the lard for lots I, II, V, and VI. For lots I and V, a mixture of 10 pounds of lard, 0.5 pounds of soya lecithin,[3] and 30 pounds of water were recycled through the homogenizer at 2500 pounds pressure until microscopic examination showed that the fat globules were 2 microns or less in diameter. For lots II and VI, the same fat, phospholipid, water emulsion was cycled through the homogenizer twice at a pressure of 1000 pounds per square inch. Microscopic examination showed a particle size of 6–8 microns in diameter. When the same fat, phospholipid, water emulsion was mixed in a Waring Blendor of 1 liter capacity for 30 seconds, a particle size ranging from 2–20 microns was obtained; this preparation was used for lots III and VII. The latter preparation procedure was used for lots IV and VIII except that no soya lecithin was used.

Lard was used as a source of fat because of its low cost and its similarity to the fat in sow's milk.

The colostrum-fed pigs were weighed on the 2nd, 8th, 15th, 21st, and 28th days. The no-colostrum animals were weighed at birth and at weekly intervals thereafter. For reasons of economy, all experiments were terminated when the pigs were 28 days old.

The feces were collected from each animal for two five day periods, beginning at 10 and again at 20 days of age. The feces were air dried and the fat content determined using Saxon's alcohol ether-extraction method described by Hawk, Oser, and Summerson (1948). The fecal fatty acids were titrated with normal alcoholic KOH, and calculated as stearic acid.

Results

The average growth and efficiency of feed utilization data for each of the individual lots in both colostrum and no-colostrum groups are summarized in table 2. There were no significant differences in the average daily gains between the lots where emulsification of the fat was effected by the use of soya lecithin. However, when no phospholipids were used in attempts to homogenize the fat, only the 2-day-old pigs survived. The no-colostrum pigs, when offered milk in which the lard had

[3] Lecithin was secured from Associated Concentrates Incorporated, Woodside, Long Island, N. Y.

not been homogenized with soya lecithin (IV) scoured severely, became dehydrated, weak, and died in 4–5 days. None of the therapeutics used, streptomycin, aureomycin, or sulfathalidine, were of any beneficial effect. The colostrum-fed pigs on the same fat treatment (IV) also scoured for the first week on experiment, however, the scours were milder, and their average daily gains were equal to those of the other lots.

TABLE 2. EFFECT OF FAT PARTICLE SIZE AND PHOSPHOLIPID ON GROWTH AND FEED UTILIZATION OF BABY PIGS

Colostrum—2-day

Lot no.	Items compared	No. of pigs	Initial weight	Final weight	Av. da. gain	Kg. solids per kg. gain
			lb.	lb.	lb.	
I	Less than 2 microns	4	3.3	12.8	0.36	1.56
II	6 to 8 microns	4	3.2	12.7	0.36	1.56
III	2 to 20 microns	4	3.5	13.6	0.39	1.46
VI	No emulsification	4	3.3	12.7	0.36	—

No colostrum

Lot no.	Items compared	No. of pigs	Initial weight	Final weight	Av. da. gain	Kg. solids per kg. gain
			lb.	lb.	lb.	
V	Less than 2 microns	4	2.3	13.0	0.38	1.49
VI	6 to 8 microns	4	2.9	13.2	0.36	1.55
VII	2 to 20 microns	4	2.5	12.5	0.36	1.60
VIII	No emulsification	2	2.4	+[1]	+	+

[1] Death—first week.

The particle size had no effect on the efficiency of feed utilization of 2-day pigs where phospholipid was used in the homogenization of the fat. In similar treatments with pigs receiving no colostrum, a trend for the efficiency to decrease slightly with increase in particle size was observed.

The fat digestion coefficients and percentages of fat in air-dry feces appear in table 3. No consistent differences in fat digestion due to differences in particle size were observed. Pigs receiving colostrum, however, tended to have slightly higher average coefficients of digestibility than the no-colostrum group. Due to the large within group variations these differences were not significant. No significant differences in the percentage of fat in air-dry feces due to either particle size or colostrum feeding were found.

No effect of homogenization on lipolysis in the digestive tract, as evidenced by the percentage of free fatty acids in the fecal fat, was apparent. Pigs without benefit of colostrum had a higher percentage of free fatty acids in the fecal fat.

The digestion coefficients 41–49 reported here are not to be interpreted as absolute values. The animals were bowl-fed and although

TABLE 3. EFFECT OF FAT PARTICLE SIZE AND PHOSPHOLIPID OF FAT UTILIZATION BY BABY PIGS

Average digestion coefficients

Items compared	Less than 2 microns	6 to 8 microns	2 to 20 microns	No emulsification
Colostrum	45	49	48	—
No colostrum	42	41	41	—

Average percentages of fat in air-dry feces

Items compared	Less than 2 microns	6 to 8 microns	2 to 20 microns	No emulsification
Colostrum	69.25	66.34	64.80	—
No colostrum	65.32	67.12	71.20	—

Average percentage free fatty acids in fecal fat

Items compared	Less than 2 microns	6 to 8 microns	2 to 20 microns	No emulsification
Colostrum	73.9	76.4	76.7	—
No colostrum	87.2	80.8	82.8	—

they were in individual cages, considerable error was involved. No accurate method of estimating the amount wasted was possible. Thus each pig was credited as consuming all the milk allowed; further the milk wasted was in part caught on the cheesecloths beneath the screen bottomed cage and weighed with the feces. However, the errors introduced were assumed to be the same for each pig, thus relative comparisons between treatments can still be made. No feed consumption and fecal data were evaluated for pigs where unemulsified lard was fed. The data would have been of little value since the pigs had lard all over their bodies as well as all over the cages.

Discussion

From the results of these experiments it would appear that homogenization of the fat or the addition of phospholipids has little or no effect on the fat utilization and subsequent growth of 2-day-old pigs.

The processes of fat absorption are not completely understood. Basically however it appears to be clear that emulsification in the intestine is of great importance. However Frazer (1949) has shown that phospholipids do not form an essential part of the intestinal emulsifying system. Verzer and Laszt (1934) demonstrated the importance of phosphate in enhancing fat absorption. Sinclair (1936) has clearly shown that phospholipids are formed in the intestinal cell during fat absorption, and that the diet must provide the raw material for their formation. Thus the phospholipids, as such, may not be a dietary essential. Augur *et al.* (1947) reported a stimulating effect of lecithin (16.7% in relation to the fat) on the rate of absorption and the coefficient of digestibility of fats fed to rats. On the other hand, Shoshkes *et al.* (1950) reported that the absorption of orally fed corn oil by the rat was unaffected by the presence soybean phosphatide or Tween 80 (20% in relation to the fat).

The results of research to detect the effect of particle size on fat utilization are also contradictory. Holt (1935) in work with humans reported that the size of the fat particle has no influence on fat absorption. On the other hand, working with dairy calves Kastelic *et al.* (1950), Bate *et al.* (1949) were able to show a favorable response.

It is clear from the afore discussion that the absorption of fat is not a simple process, and further that no one factor is paramount but rather that an interaction of many factors makes for efficient fat utilization. Our results indicate no benefit from either homogenization or the addition of 0.3 percent phospholipid for 2-day-old pigs. It may be that the amount of phospholipid used (5% of the fat) was too low to exhibit a stimulating effect on fat utilization. Phospholipid content of sow's milk fat, however, was reported by Sheffy *et al.* (1951) to be between 1 and 2 percent of the fat.

The response by pigs not receiving any colostrum suggested a dietary need for phospholipid. Particle size, however, had very little effect as long as phospholipid was present. In pigs both with and without colostrum, phospholipid seemed to be of some benefit in reducing scouring. Similarly there was some tendency for pigs receiving fat of smaller particle size to cease scouring earlier.

It was demonstrated that pigs can successfully be raised without the benefit of colostrum if antibiotics are used. This tends to indicate that the factors in colostrum heretofore believed to be indispensable to the baby pig can, at least under experimental conditions, be supplied by synthetic compounds.

Summary and Conclusions

A semisynthetic milk was used to test the effect of particle size and phospholipids on growth and fat utilization of baby pigs.

There were no significant differences in the average daily gains or feed utilization between the lots where emulsification of the fat was effected by the use of 5 percent soya lecithin.

When no phospholipids were used only the 2-day-old pigs survived. Their daily gains were not different from the phospholipid-fed lots.

There was no difference in the fat utilization of colostrum or no-colostrum pigs regardless of particle size when phospholipid was fed. Phospholipid appeared to be of some benefit in reducing scours.

Pigs without the benefit of colostrum were successfully raised on a semisynthetic ration.

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VITAMIN AND MINERAL SUPPLEMENTS FOR GROWING AND FATTENING PIGS IN DRYLOT

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ALTHOUGH many drylot experiments have been conducted with growing and fattening pigs to determine the value of B-vitamin supplements, little evidence has been presented concerning the use of trace minerals in drylot rations. A review of existing literature indicates that in some experiments certain trace minerals have improved drylot rations while in other trials they were apparently ineffective.

Ellis and Madsen (1941) reported a slight increase in average daily gain when 72 p.p.m. (parts per million) of manganese were added to a drylot ration. Richards (1930) and Johnson (1940 and 1943) obtained no benefit by the addition of manganese to swine rations. However, Johnson (1944) reported a slight response from a manganese supplement to a ration which contained more than 10 percent ash.

Miller and co-workers (1940) and Keith and associates (1943) found that manganese was effective in curing a lame condition often observed by the above authors. In these Pennsylvania experiments a low-protein tankage was used in the drylot ration. More recently, Grummer and associates (1950) reported that manganese supplementation improved the rate and economy of gain made by pigs fed a growing and fattening drylot ration which contained no protein concentrate of animal origin.

In 1945, Braude found that a drylot ration which contained fish meal was not improved by additional copper.

Grashius (1932), Klosterman and co-workers (1950), and Speer and associates (1950) stated that various combinations of trace minerals have improved certain drylot rations.

Likewise, Robison (1950) and Klosterman *et al.* (1950) demonstrated that cobalt was effective in correcting the deficiencies of drylot rations.

It is interesting to note that Carroll and Mitchell (1927), Mitchell

[1] The authors wish to acknowledge the aid given by the swine farm manager, Mr. John Dunn, and his assistants in the conduct of these trials. Associate Professor C. R. Henderson was of valuable assistance in planning and analyzing the results of these experiments.

[2] This study was conducted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy in Animal Husbandry. Present address, University of Arkansas, Fayetteville, Arkansas.

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and others (1937), Isaachsen (1932), and Longwell and Severson (1944) found various combinations of trace minerals to be ineffective in improving drylot rations.

A series of experiments was begun at the Cornell Station to determine the value of additions of cobalt, copper, iron, and manganese to a drylot ration which contained no source of animal protein (Willman, McCay, and Morrison, 1947) (Goodwin, 1948). Later trials were also designed to compare the efficiency of the trace mineral supplement with cow manure, sod and dirt, or certain APF concentrates containing aureomycin or streptomycin.

TABLE 1. TRACE MINERAL CONTENT OF RATIONS USED

(parts per million)

	Basal ration[1]	Basal ration + trace minerals
Cobalt	0.12	1.0
Copper	13.0	13.8
Iron	110.0	118.8
Manganese	20.0	108.0

1 Trace mineral content was determined by Dr. K. C. Beeson, Federal Nutrition Laboratory, Ithaca, New York.

Procedure

In accordance with recommended management practices, the dams of all pigs used in these trials were fed some meat scraps and at least 10 percent of good quality alfalfa hay or pasture throughout the gestation-lactation periods. In all but two trials the pigs were kept on concrete floors from birth until soon after weaning (56 days). At this time the pigs were randomly assigned by breed, sex, and litter to a particular treatment. All lots were self-fed on concrete floors during the feeding period.

The basal ration used in all trials was composed of ground yellow corn, soybean oil meal (solvent or expeller), 10 percent of ground, sun-cured alfalfa hay, dicalcium phosphate, ground limestone, and iodized salt. This ration was mixed to contain about 20 percent crude protein until the pigs weighed 75 pounds, 16 percent for the period from 75 to 125 pounds, and 14 percent during the remainder of the experiment.

The elemental amounts of trace minerals contained in both the supplemented and unsupplemented rations are shown in table 1. The

following amounts of trace minerals were added in these trials: 0.88 p.p.m. cobalt, 0.88 p.p.m. copper, 8.8 p.p.m. iron (ferrous ion), and 88 p.p.m. manganese.

The quantity of copper and iron added was insignificant in proportion to the amounts contained in the basal ration, but perhaps the minerals in this ration were not completely available to the experimental animals.

The sod and dirt and the cow manure were supplied free-choice in small wooden boxes. The sod and dirt contained the following amounts

TABLE 2. SUMMARY OF TRIALS IN WHICH THE PLANT-PROTEIN BASAL RATION WAS SUPPLEMENTED WITH FOUR TRACE MINERALS, COW MANURE, OR SOD AND DIRT

Treatment	Basal	Basal + four trace minerals	Basal + sod and dirt	Basal + cow manure
Number of trials	3	3	3	3
Total number of pigs	23.6[1]	24	24	23.6[2]
Av. feeding period (days)	90.7	81	86.3	81.7
Av. initial weight (lbs.)	54.9	54.4	53.9	55.2
Av. final weight (lbs.)	148.2	149.9	148.3	146.2
Av. daily gain (lbs.)	0.99	1.17*	1.09*	1.10*
Av. daily feed (lbs.)	4.22	4.55	4.56	4.36
Av. feed required for cwt. gain (lbs.)	425	386	419	400

* Analysis of variance indicates that the supplemented lots gained significantly faster ($P \leq .05$) than the basal fed lots, but there was no statistically significant difference among the gains of the treated lots.

[1] One pig died from an unknown cause and another was removed due to a fluid accumulation in the scrotum.

[2] One pig died from an unknown cause.

of trace minerals: 13 p.p.m. cobalt, 21.2 p.p.m. copper, 25,400 p.p.m. iron, and 1080 p.p.m. manganese. Fresh cow manure was obtained from steers receiving a light grain feed.

Results and Discussion

Trace Minerals vs. Cow Manure vs. Sod and Dirt

A series of three trials was conducted in 1948–49 to determine the relative values of the four trace minerals, sod and dirt, or cow manure as supplements to the basal ration. The results of these trials are summarized in table 2.

In trial I the pigs used had access to legume-grass pasture before

the experiment was started. In the other two trials the pigs were kept on concrete floors during the suckling period.

The average daily gains of the basal fed lots in the three trials were as follows: trial I—1.03, trial II—1.03, and trial III—0.92 pounds per day. In only one instance did the basal lot gain faster than one of the supplemented lots; in trial III the pigs given access to sod and dirt gained only 0.91 pound per day.

The feed requirements were somewhat less consistent in the supplemented lots since three of the nine supplemented lots required more fed for a unit of gain than the basal fed lots.

TABLE 3. SUMMARY OF TRIALS IN WHICH FOUR TRACE MINERALS WERE ADDED TO THE BASAL RATION

Treatment	Basal	Basal + four trace minerals
Number of trials	4	4
Total number of pigs	30.48[1]	30.62[1]
Av. feeding period (days)	98.0	88.75
Av. initial weight (lbs.)	53.7	53.5
Av. final weight (lbs.)	156.4	158.6
Av. daily gain (lbs.)	1.04	1.20**
Av. daily feed (lbs.)	4.25	4.68
Av. feed required for cwt. gain (lbs.)	410	391

** Analysis of variance indicates that the supplemented lots gained significantly faster ($P \leq .01$) than the basal fed lots.
[1] See footnotes table 2.

Pigs which consumed the sod and dirt or cow manure in largest amounts consistently gained significantly faster than the basal fed lots. Consequently, for pigs fed a plant-protein ration in drylot, considerable improvement in rate of gain can be produced by allowing the pigs access to cow manure or sod and dirt. In these three trials pigs supplied with supplementary amounts of the four trace minerals gained appreciably faster than those given free access to fresh cow manure or sod and dirt.

Addition of Trace Minerals to Plant-Protein Ration

In all, a total of four experiments were conducted in which the plant-protein ration was supplemented with the four trace minerals (0.88 p.p.m. cobalt, 0.88 p.p.m. copper, 8.8 p.p.m. iron, and 88 p.p.m. man-

ganese). The trace mineral content of the basal ration in the three trials was the same as that shown in table 1. In the fourth trial the unsupplemented basal ration contained the following amounts of the four minerals: 0.08 p.p.m. cobalt, 7.5 p.p.m. copper, 85 p.p.m. iron, and 16.7 p.p.m. manganese. Results of all four trials are summarized in table 3.

The trace mineral additions significantly improved ($P \leqq .01$) the rate of gain made by weanling pigs fed a drylot ration containing no feeds of animal origin. This supplement also reduced the feed required for a unit of gain. In each of the four trials, those lots fed the trace minerals consumed more feed per day than the pigs fed the basal ration alone. Apparently, at least part of the beneficial effect of the trace minerals was due to a stimulating effect on the pigs' appetites.

In two of the four trials, the pigs had access to legume-grass pasture during the suckling period. Nevertheless, in all four trials the supplemented lot gained appreciably faster than the pigs fed the basal ration alone.

Basal Ration vs. Trace Minerals vs. Meat Scraps Ration

It seemed desirable to compare the all-plant-protein ration containing trace minerals with a control ration. In the control ration an average level of 10 percent meat scraps replaced a protein equivalent of soybean oil meal in the basal ration. (The meat scraps contained 55 percent crude protein.) A summary of the results of these two trials is presented in table 4. The pigs used in one of the trials had access to legume-grass pasture during the suckling period.

In each trial the supplemented lots gained faster than the basal fed lot. The two lots fed the meat scraps ration consumed more feed per day than did those pigs fed the basal ration alone or with trace minerals added. The lots fed the meat scraps ration gained slightly faster than the trace-mineral-supplemented lots. However, the pigs fed the meat scraps ration required considerably more feed for a unit of gain than the lots fed either the basal ration alone or with trace minerals included.

One of the lots fed the basal ration alone made very efficient gains and required only 364 pounds of feed for a hundredweight gain. Consequently, in these two trials, the pigs fed the basal ration alone had an average feed requirement lower than those fed the same ration supplemented with trace minerals.

Trace Minerals vs. Supplements Which Contain Antibiotics and Vitamin B_{12}

Since the four trace minerals had consistently improved the rate of gain made by pigs fed a plant-protein ration, an experiment was conducted to compare vitamin B_{12} supplements containing aureomycin or streptomycin with trace minerals alone. The results of this trial are summarized in table 5.

All lots were fed the trace mineral supplement, but in this trial the amount of added manganese was reduced from 88 p.p.m. to 66 p.p.m.

TABLE 4. MEAT SCRAPS RATION COMPARED WITH THE BASAL RATION ALONE OR WITH TRACE MINERALS ADDED

Treatment	Basal	Basal + four trace minerals	Meat scraps ration
Number of trials	2	2	2
Total number of pigs	16	16	16
Av. feeding period (days)	106.5	97.5	94
Av. initial weight (lbs.)	50.6	51.4	51.6
Av. final weight (lbs.)	167.8	168.9	171.1
Av. daily gain (lbs.)	1.11	1.24**	1.28**
Av. daily feed (lbs.)	4.21	4.82	5.39
Av. feed required for cwt. gain (lbs.)	382	390	420

** Analysis of variance indicates that the supplemented lots gained significantly faster ($P \leqq .01$) than the basal fed lots. There was no statistically significant difference between the gains of the treated lots.

The other trace minerals were added at the same level as in the previous trials.

During the entire feeding period from weaning to 180 pounds little improvement was obtained in rate of gain by adding 0.25 percent of an aureomycin-vitamin B_{12} supplement. From weaning to 100 pounds this supplement increased the rate of gain, but this difference failed to be statistically significant. Although the pigs fed the aureomycin-vitamin B_{12} supplement consumed less feed per day than those fed the basal ration, the supplemented lot required appreciably less feed for a unit of gain.

The aureomycin-vitamin B_{12} did not improve the feed efficiency of a meat scraps control ration which contained trace minerals. In the period from weaning to 100 pounds the aureomycin-vitamin B_{12} supplement

appreciably improved the rate of gain when added to the meat scraps control ration, but again this difference failed to be statistically significant.

The efficiency of feed utilization was not improved by the addition to the plant-protein basal ration of 0.15 percent of a streptomycin-vitamin

TABLE 5. TRACE MINERALS, AUREOMYCIN APF, AND STREPTOMYCIN APF AS SUPPLEMENTS TO THE PLANT-PROTEIN RATION

Treatment	Basal incl. trace minerals	Basal + 0.25%[1] aureomycin APF	Basal + 0.15%[2] streptomycin APF	Meat scraps ration	Meat scraps ration + 0.25%[1] aureomycin APF
Total number of pigs	9	9	9	9	9
Av. feeding period (days)	112	112	116	112	116
Av. initial weight (lbs.)	40.7	40.6	40.8	40.3	40.1
Av. final weight (lbs.)	184.2	188.2	178.9	184.2	179.6
Av. daily gain (lbs)	1.28	1.32	1.19	1.28	1.20
Av. daily feed (lbs.)	5.30	4.83	4.80	5.09	4.88
Av. feed required for cwt. gain (lbs.)	413	367	403	395	405
Av. daily gain to 100 (lbs.)	1.20	1.29	1.12	1.02	1.17
Millimicrograms of vitamin B_{12} per g. of feces[3]	450	154	371	264	218
Millimicrograms of vitamin B_{12} per g. of fecal dry matter	652	212	520	363	309

In this trial the pigs used had no acess to pasture before the experiment was started.

[1] Aureomycin-vitamin B_{12} supplement was fed to supply approximately 17.5 micrograms of vitamin B_{12} activity per pound of feed. It was lots 30 and 50 of Lederle's APF Supplement No. 5, and was supplied by courtesy of Dr. T. H. Jukes, Lederle Laboratories, Pearl River, New York.

[2] Streptomycin-vitamin B_{12} supplement was fed to supply approximately 17.5 micrograms of vitamin B_{12} activity per pound of feed. This supplement is known as MK-42 and was supplied by courtesy of Dr. D. F. Green, Merck and Co., Rahway, New Jersey.

[3] Vitamin B_{12} assays were made in the Poultry Nutrition Laboratory, Cornell University, by Mrs. Betty Brown and Dr. H. T. Peeler.

B_{12} supplement. This supplement also failed to improve the rate of gain from weaning to either 100 or 180 pounds.

Some evidence has been obtained in earlier work at this station (Noland, Willman, and Morrison, 1951) indicating that trace minerals were effective in increasing the intestinal synthesis of vitamin B_{12}. Therefore, composite fecal samples were taken from all lots and assayed microbiologically for vitamin B_{12}. The method of Peeler and associates (1949) was used in making these determinations. The assays, as reported in table 5, were conducted as follows: the feces were digested

with papain and takadiastase and corrections were made for desoxyriboside activity by the alkali digestion method. The results of microbiological assays indicated that the single supplement of the four trace minerals was somewhat more effective in increasing the amount of intestinal synthesis of vitamin B_{12} than a combination of trace minerals and aureomycin or streptomycin-vitamin B_{12} supplements. Likewise, the feces of pigs fed the trace mineral supplement with the plant-protein ration contained considerably more vitamin B_{12} than pigs fed the meat scraps rations with the trace minerals.

Summary

A series of experiments was conducted with a growing and fattening drylot ration containing no feeds of animal origin. This ration was improved in three different trials by adding small amounts of four trace minerals (cobalt, copper, iron, and manganese) or allowing the pigs free access to fresh cow manure or sod and dirt. The pigs fed trace minerals made somewhat more rapid gains, but the difference in the effectiveness of these three supplements was not statistically significant.

A highly significant increase in rate of gain was obtained in four trials when the four trace minerals were added to the basal ration. This supplement also reduced the feed required for a unit of gain.

In two trials, the substitution of meat scraps for a part of the soybean oil meal in the basal ration was no more effective in correcting the deficiencies of the basal ration than addition of the four trace minerals to the basal ration.

Vitamin B_{12} supplements containing either aureomycin or streptomycin were also compared with the plant-protein ration containing trace minerals. The supplement which contained aureomycin was most effective in improving the rate of gain of pigs from weaning to 100 pounds. During the entire period from weaning to 180 pounds very little improvement in rate of gain was produced by this supplement. Considerable improvement in efficiency of gain was noted when this supplement was added to the basal ration.

Similarly, pigs fed a ration containing meat scraps and the aureomycin-vitamin B_{12} supplement gained somewhat faster during the period from weaning to 100 pounds than those pigs fed the meat scraps ration and trace minerals. From weaning to 180 pounds the supplemented lot gained no faster than the lot fed the meat scraps ration alone. No improvement in economy of gain was produced by the supplement. In both lots receiving the aureomycin-vitamin B_{12} supple-

ment, the most beneficial effect on rate of gain was obtained in the period from weaning to 100 pounds. In neither lot were the differences in rates of gain statistically significant.

A vitamin B_{12} supplement which contained streptomycin failed to improve either the rate or efficiency of gain during the period from weaning to 100 or 180 pounds.

Some evidence is also presented which indicates that a single supplement of the four trace minerals was more effective in promoting the intestinal synthesis of vitamin B_{12} than supplements of the four trace minerals and aureomycin or streptomycin-vitamin B_{12} supplements.

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STILBESTROL, EFFECT OF SUBCUTANEOUS IMPLANTATION ON GROWING-FATTENING SWINE

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RECENT investigations with sex hormones have demonstrated that subcutaneous implantation of diethyl stilbestrol pellets, and to a lesser extent, testosterone pellets, have resulted in marked increases in rate of gain and feed efficiency in beef heifers (Dinusson, Andrews, and Beeson, 1950), beef steers (Andrews, Beeson, and Harper, 1949), and lambs (Jordan, 1950; Pope *et al.*, 1950). However, stilbestrol implanation in suckling lambs gave no advantage, (Jordan and Dinusson, 1950). Some effects of the use of stilbestrol on growing-fattening swine are presented in this paper.

Materials and Methods

Pigs of the Duroc and Chester White breeds were used in these studies. All pigs were self-fed practical swine rations (table 1).

At the period of initial weighing, the pigs were allotted on the basis of weight, breed, and sex. In experiments I and III, a 12 milligram pellet of stilbestrol was implanted subcutaneously in the ear. It was thought that this would minimize any possible danger as the result of pellet residue. In experiment II, 24 milligrams were used. Difficulties were encountered from this site of implantation because of cystic encapsulation of the pellets; therefore in experiment IV, the site of implantation was changed to the dorsal region of the neck in the gilts and in the scrotal sac for the barrows.

Feed records were kept for all tests but because of lack of space, all pigs in experiment III were fed together. In some of the experiments it was necessary to weigh the pigs off trial at 180 pounds in order to use them in judging classes.

Results and Discussion

There was no consistent stimulus to gain as the result of treatment. It appeared that the pigs treated at weights from 90 to 100 pounds

[1] Contribution from the Department of Animal Husbandry, Agricultural Experiment Station of North Dakota Agricultural College, Fargo. Published with the permission of the director.

responded somewhat more than those treated at lighter weights but the differences were not great.

In each case where measured, the untreated pigs required from 5.2 to 13.7% more feed per pound of gain. This was most noticeable for the pigs treated at the lighter weights.

Gilts appeared to respond more uniformly to treatment than barrows. However, this treatment, in the dosages used, cannot be recommended for practical use because of danger of prolapse of the uterus from over stimulation. Out of eleven gilts so treated, four suffered a prolapse. Mammary development and teat growth was evident on all gilts. About

TABLE 1.—RATIONS

Ration: Used in:	A Exp. I	B Exp. II[1] Exp. III	C Exp. IV[2]
Barley	80.0	....	....
Corn (#2)	....	72.5	84.0
Meat Scraps (55%)	9.0	5.0	5.0
Soybean oil meal (44%)	5.0	15.0	9.0
Ground alfalfa (dehydrated)	5.0	5.0	....
Brewers yeast (41%)	0.5	1.0	1.0
Steamed bonemeal	....	1.0	0.5
Trace mineral salt	0.5	0.5	0.5
	100.00	100.00	100.00

[1] Plus 25 gms. Lederles APF #5.
[2] Plus quadrex to furnish vitamins A and D.

3 days post implantation, all gilts showed extreme swelling of external genitalia which never returned to a normal anestrus state during the trial.

The barrows treated also showed mammary development and teat growth, but to a lesser extent than the gilts. Renewed sex desire and ability for erection was noted. This was particularly true for the pigs where the pellets were implanted in the scrotal cavity.

Summary

Stilbestrol, implanted as a pellet subcutaneously, did not consistently stimulate gains of growing-fattening pigs as with beef cattle and lambs.

The non-treated controls required from 5.2 to 13.7% more feed per hundred pounds gain than did the treated pigs.

Treatment of gilts with the levels used is not to be recommended because of prolapse of the uterus as a result of the stilbestrol.

TABLE 2. RESULTS OF SUBCUTANEOUS IMPLANTATION OF STILBESTROL PELLETS ON GROWTH AND FEED EFFICIENCY OF HOGS

Experiment & Date	Lot number	Pigs per lot	Treatment & level, mgms.	Sex[1]	Initial wt. (Av. lbs.)	Final wt. (Av. lbs.)	Av. Daily gain	Days	Feed/cwt gain	% more feed
I 1949	1	20	Ear, 12	18 ♂ 2 ♀	98.1	182.2	1.75	48	494.9	
	2	20	None	18 ♂ 2 ♀	98.0	176.5	1.64	48	521.7	5.4
II 1950	1	17	Ear, 24	♂	45.4	161.8	1.48	75	326.0	
	2	17	None	♂	45.4	163.8	1.54	75	377.6	13.7
III 1950		3	Ear, 12	♀	78.3	207.3	1.96	66	Average	
		3	None	♀	82.0	205.0	1.86	66	for	
		5	Ear, 12	♂	79.4	197.2	1.79	66	group	
		5	None	♂	86.2	207.6	1.83	66	367.6	
IV 1951	1	6	Neck, 12	♀	83.8	191.8	1.96	55	333.6	
	2	6	None	♀	84.2	191.0	1.94	55	357.9	7.3
	3	6	Scrotum, 12	♂	88.7	196.7	1.96	55	371.1	
	4	6	None	♂	89.3	201.5	2.04	55	390.5	5.2

[1] ♂ barrows, ♀ gilts.

Stilbestrol treatment caused teat development in both sexes, a mild nymphomaniac response and extreme swelling of external genitalia of gilts, and in barrows, a restored ability for erection and renewed sex desire.

Subcutaneous implantation in the ear is not to be recommended because of greater chance for encapsulation or cyst formation around the pellet in that area.

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EFFECTS OF STILBESTROL AND TESTOSTERONE PELLETS IMPLANTED INTO GROWING-FATTENING PIGS[1, 2]

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STUDIES have been carried out on the effect of stilbestrol and testosterone implants in sheep and cattle. The gains of 70-pound wether lambs during a 68-day feeding period were increased significantly by implants of stilbestrol and testosterone (Andrews, Beeson and Harper, 1949); all of the treated groups required less feed per pound of gain than the control lambs. Carcass quality appeared to be improved by the testosterone pellets, but was possibly depressed by stilbestrol. In later work Jordan and Dinusson (1950) treated suckling lambs one to two months of age with stilbestrol and found no effect on average daily gain.

Dinusson, Andrews and Beeson (1950) demonstrated that growth rate, feed efficiency, and feed consumption of 500-pound beef heifers on 140-day feeding trial were significantly increased by stilbestrol pellet implantation. Also the treatment of heifers with testosterone propionate appeared to stimulate growth, but the effect was of short duration. In studies with yearling steers (Andrews, Beeson and Johnson, 1950) the stilbestrol implanted animals outgained the controls, but the testosterone group failed to equal the gains made by the controls. The stilbestrol steers required less feed per 100 pounds of gain and the testosterone group required more than the controls. There were no significant differences in the carcass grades between any of the groups.

No work appears in the literature on the effects of steroid hormones on growth and fattening of pigs. This report covers a study of the gains and carcasses of feeder pigs implanted with pellets of stilbestrol and testosterone.

Materials and Methods

For this work 37 purebred Chester White and 5 purebred Poland China feeder pigs averaging 43 pounds in weight were allotted at

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random into six lots. Two lots comprised each experimental group—testosterone implanted, stilbestrol implanted, and control. The treated pigs were implanted twice during the feeding period—at the beginning and again 12 weeks later. Fifteen mg. pellets of testosterone propionate and 12 mg. pellets of stilbestrol were used. Implantations were made in the hind flank.

Weights of the pigs were recorded at two-week intervals prior to the sixteenth week and at weekly intervals thereafter. The pigs were slaughtered on the weigh-day they reached or first exceeded 210 pounds.

The following carcass data were collected: dressing percentage; weight of leaf fat; weight of regular ham; percent of external fat (skin included) in the regular ham; length of carcass—measurement made from first rib to the aitch bone; seediness of belly—width of seed at hind nipple on the freshly cut commercial belly; eye muscle measurements—product of width times depth as measured just caudal to the last rib; fat back thickness—five different measurements (made at the first, seventh and thirteenth ribs, and at the third and last lumbar vertebrae); length of femur—over-all length from the most distal to most proximal part (line of measurement parallel to long axis of bone); specific gravity of femur—by water displacement after overnight submersion in water. Gross measurements and observations were also taken on the reproductive organs of the pigs after slaughter.

Results

A summary of the means for the different variables is presented in table 1. There were no significant differences between the stilbestrol or testosterone treated groups and the controls in any of the characteristics with the exception of seediness as measured on the fresh belly.

In addition the average daily gains by intervals between successive weigh-periods were analyzed by the analysis of variance technique. This was done to detect possible growth stimulation or inhibition which might have occurred for short periods but then have been masked in the over-all average figures by compensatory changes at other periods. No significant interaction of treatment and period was found by this analysis.

The reproductive organs of the testosterone treated gilts did not appear to differ greatly from the controls. However, the stilbestrol treated gilts did not have as large ovaries or as large follicles as did the testosterone or control animals. The walls of the uteri were markedly thickened and the vaginal mucosa showed a roughened granular ap-

pearance as compared with the other groups. No histological studies were made of the tissues.

Both the testosterone and stilbestrol treated barrows differed from the control barrows. Treatment effects in general were greatest in the stilbestrol animals. As an example—the largest seminal vesicles in the control group were 17 x 8 x 3 mm.; in the testosterone group 21 x 10 x 5 mm.; and in the stilbestrol group 93 x 26 x 15 mm. Growth stimulation and secretion were also noted in the prostate and Cowper's glands, and there was enlargement of the preputial diverticulum in the treated groups.

TABLE 1. TREATMENT MEANS

Items studied	Testosterone	Stilbestrol	Control
Length of carcass (in.)	28.8	29.0	29.0
Fat back thickness (in.)	1.9	1.9	1.9
Percent of external fat (skin included) in the regular ham	36.8	36.7	36.8
Eye muscle (l x w—sq. in.)	5.2	5.4	5.7
Length of femur (cm.)	18.2	18.2	18.2
Specific gravity of femur	.795	.795	.816
Weight of regular ham (lbs.)	15.0	15.2	15.3
Weight of leaf fat (lbs.)	5.1	5.6	4.8
Seediness of belly (in.)	.15	.85**	.19
Average daily gain (lbs.)	1.25	1.29	1.28
Initial weight (lbs.)	41	43	45
Feed per cwt. gain (lbs.)	386	376	384
Daily feed consumption (lbs.)	4.75	4.82	4.80
Dressing percentage	72.4	72.1	72.8

** Highly significant difference from control ($P<0.01$).

Discussion

This experiment gave no evidence of hormonal effect on growth and fattening of swine in contrast to the results obtained by others in sheep and cattle. The question might well be raised as to whether sufficient hormone was implanted. In reply to this, it will be noted that the dosages of both stilbestrol and testosterone were great enough to produce demonstrable effects on the reproductive organs.

Lorenz (1945) reported that subcutaneous implantation of stilbestrol into cockerels caused a marked increase in the quantity of depot fat and fat stored in the muscle tissue with little or no effect on growth and economy. This is in contrast to the most pronounced effects in sheep and cattle, as noted above, which are accelerated growth rate and increased economy of gain. The pig appears to be unlike both the

chicken so far as fattening is concerned and sheep or cattle so far as growth and economy are concerned. The pig is characterized by a simple stomach as contrasted to these other forms. The possibility of the rumen being important in the ability of stilbestrol to bring about increased growth and economy might well be examined in sheep and cattle. This possibility is emphasized also by the finding of Jordan and Dinusson (1950) that suckling lambs one to two months of age did not respond to stilbestrol. Such lambs may be too young for the rumen to be highly functional.

Summary

The effects of implanting pellets of stilbestrol and testosterone subcutaneously were studied with 42 growing-fattening pigs. Two lots of seven pigs each were assigned to each experimental group—control, testosterone implanted, and stilbestrol implanted. The implantations were made at the beginning of the experiment and 12 weeks later. The pigs averaged 43 pounds at the start of the experiment and were slaughtered as they reached 210 pounds. The following characteristics were studied: average daily gain, feed per 100 pounds gain, daily feed consumption, dressing percentage, length of carcass, weight of regular ham, percent of external fat in the regular ham, eye muscle measurement, fat back thickness, length of femur, specific gravity of the femur, weight of leaf fat, and seediness of the fresh belly. Of these characteristics, seediness of the belly in the stilbestrol group is the only one that showed a significant deviation from the control.

The reproductive organs of the treated pigs showed definite evidence of hormonal stimulation.

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DISTRIBUTION OF INTRAVENOUSLY INJECTED RADIOACTIVE PHOSPHORUS (P^{32}) AMONG SWINE TISSUES[1]

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THE importance of phosphorus in animal physiology and husbandry has led to many investigations of the metabolism of this element. Recently, the production of artificially radioactive phosphorus (P^{32}) has furnished a new experimental approach to phosphorus metabolism.[5] By "labeling" some phosphorus atoms (e.g., making them radioactive) and using them as "tracers", it is possible to follow the distribution of these atoms, and phosphorus generally, among the tissues of an animal. By determining the distribution of such phosphorus atoms at various times after administration, it is possible to outline the "pathways" which phosphorus follows through the animal body.

This paper reports the distribution of plasma inorganic phosphorus among the tissues of swine at different ages, and at different times after injection. The procedures used here permit an "over-all" evaluation of the phosphorus metabolism of the various tissues. The "usefulness" of such information is to extend the "history" of the phosphorus which the animal takes in through its diet.

Method

Three groups of swine of different ages (approximately 2, 4 and 8 months) were selected from the Animal Husbandry herd. A description of these animals is given in table 1. An isotonic buffered solution, containing P^{32} labeled sodium phosphate, was injected into one of the marginal ear veins. One series of animals (H2-H4) was slightly anaesthetized with ether prior to the injection; all others were manually restrained. Following the injection, the animals were returned to their usual routine (feeding, etc.) until time of slaughter.

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[5] For a complete description of tracer methods and an extensive bibliography of tracer experiments, one should refer to Siri's book (1949).

TABLE 1. DESCRIPTION OF EXPERIMENTAL ANIMALS

	2 months old			4 months old				8 months old		
Experiment No.[1]	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
Breed	Duroc	Duroc	Duroc	Hamp.	Duroc	Duroc	Duroc	Poland-Hamp. X	Duroc	Poland-Hamp. X
Sex[2]	♀	♀	♀	♂	♀	♂	♂	♀	♀	♀
Age (killed) (days)	74	74	69	127	134	134	134	231	243	232
Time (hrs. post-inj.) when killed	5.5	24	48	1	6	24	48	6	24	48
Body weight (kg)	12.7	15.5	19.1	26.4	30.9	30.9	35.4	91.4	92.7	86.4
P^{32} dose (mc)[3]	1.45	1.52	1.52	4.26	4.49	5.34	5.10	5.06	5.32	5.32
kg/mc[4]	8.77	10.2	12.6	6.21	6.90	5.80	6.94	18.1	17.4	16.2

[1] H1 and H2; H6 and H7; and H8 and H10 are littermates.

[2] ♂=castrate.

[3] 1 mc = 1 millicurie = 2.22×10^9 radioactive disintegrations per minute; the measurements of radioactivity in the tissue are given in microcuries (μc); 1 μc = 0.001 mc.

The amount of phosphorus which is represented by 1 mc of phosphorus is quite small, being 4.7×10^{-6} mg P^{32}.

[4] This is the "Correction Factor" for specific activity; Specific Activity × factor = "Standardized" Specific Activity.

The animals were sacrificed at varying times after the injection. The smaller animals were stunned with a blow on the head, then killed by exsanguination. The larger animals were shot and exsanguinated. The desired tissues were removed, freed of extraneous material, and allowed to drain of blood in a closed bottle. Samples of the tissues were then weighed, dried at 105°C, and re-weighed. Smaller samples (1 gm.) of the dried tissues were treated with magnesium nitrate (1 ml. of a 10% solution), redried, and ashed at 500°C. The ash was dissolved in a standard volume (20 ml.) of dilute hydrochloric acid.

Aliquots of these ash solutions (0.2 ml.) were pipetted on copper discs (planchets), on which smaller discs of lens paper had been placed to insure an even distribution, and dried. The radioactivity contained was determined with a Geiger counter. Phosphorus content of these same solutions was determined colorimetrically by the method of Fiske and SubbaRow (1925). A tri-chloroacetic filtrate of the post-mortem plasma was also prepared and similarly assayed for radioactivity and phosphorus content.

Some pathology was noted in the experimental animals, which was not considered to have a great influence on the results. H5 and H6 had a few intestinal parasites (round worms). H9 had one lobe of its lung congested, and, apparently, an increased white blood cell count, since the "buffy coat" observed in centrifugation of blood was about four times the normal thickness. H10 had a fairly large pus pocket on the side of the neck, and several small fibrotic areas were observed on the surface of the liver.

In the course of these experiments, some information, incidental to the tracer work, was collected on the tissue composition of swine of different ages. Since these data are of interest in themselves, a summary of the phosphorus content and dry matter of the tissues analyzed, and some of the organ weights, are presented in table 2.

There are several ways in which the radioactivity of the tissues can be represented. The amount of radioactivity (per gram of tissue), called the "activity", would represent the portion of the administered phosphorus taken up by a particular tissue. For metabolic evaluation, however, the activity is insufficient since tissues low in phosphorus would have a low activity, but nevertheless could still have a very active phosphorus metabolism. To compensate for differences in phosphorus content, such data are usually reported as "specific activity".

$$\text{Specific Activity} = \frac{\mu c\ P^{32}/\text{ml. solution}}{\text{mg P/ml. solution}} = \frac{\mu c\ P^{32}}{\text{mg P}}$$

TABLE 2. COMPOSITION OF SWINE TISSUES AND SIZE OF ORGANS

	2 months				4 months				8 months			
	actual weight (gms.)	relative weight (gm./kg)	dry matter (%)	Phos. conc. mgP/gm dry	actual weight (gms.)	relative weight (gm./kg)	dry matter (%)	Phos. conc. mgP/gm dry	actual weight (gms.)	relative weight gm./kg	dry matter (%)	Phos. conc. mgP/gm dry
Biceps musc.			22.5± .2	8.3± .6			24.8±1.3	7.3± .6			26.0± .4	6.8± .1
Brain	52.± 4.	3.4±.4	21.8±1.5	14.2± .8	55.± 2.	1.8± .2	20.4±1.3	14.6± .2	68±4	.8± .04	22.1± .3	14.5± .7
Back fat			70.0±2.9	.5± .1							93.0± .4	.2± .05
Gastroc. musc.			21.9± .3	8.5± .3			23.8±1.3	7.0± .6			26.3± .5	6.3± .4
Heart	69.± .4	4.5±.5	20.3± .2	10.3± .3	137.± 7.	4.4± .1	19.9± .4	13.9± .2	260 ±23	2.9± .3	19.7± .9	9.3± .4
Kidney	39.± 3.	2.5±.1	19.6± .2	12.0± .2	60.± 5.	1.9± .1	20.0±1.	12.0± .7	128 ±7	1.4± .1	20.3± .4	10.2± .8
Liver	430.±59.	27. ±.7	27.4± .7	11.9±1.2	773.±54.	25. ±1.	28.4± .9	12.0± .4	1490 ±100	16.5± .8	27.8±1.0	14.1±1.8
Lung	171.±18.	11. ±.2	19.2± .2	12.1± .6	308.±30.	10. ± .6	18.6±1.	11.7± .9	677 ±135	7.5±1.4	19.5± .7	9.3± .9
Lymph node			20.4±1.6	12.9±1.0			22.5±1.7	12.8±1.1			16.9± .6	
Ovaries											25.1±1.1	10.6± .6
Spleen	32.± 1.	2.1±.3	21.3± .8	12.1± .2	46.± 2.	1.5± .1	22.0± .4	14.6± .5	97±8	1.1± .1	27.7± .2	12.3± .4
Stomach musc.			17.4± .3	6.4± .7			18.2± .6	5.9± .2			21.1± .9	4.9± .5
Thymus			21.4± .6	20.6± .9			27.8±1.1	14.9±1.2			22.9±1.1	14.0±2.2
Thyroid							17.7±1.7	5.4± .6			23.3[1]	6.7[1]
Tongue musc.			22.1± .1	8.4± .4			22.5± .5	8.2± .3			25.5± .5	7.0± .4

[1] One determination only.

Body weights of groups: 2 month=15.8±1.9kg; 4 month=30.9±1.8kg; 8 month=90.2±1.9kg.

TABLE 3. STANDARD SPECIFIC ACTIVITY OF TISSUES

$\mu c\ P^{32}/mg\ P$

mc P^{32} inj/kg. body weight

	2 months old			4 months old				8 months old		
	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
Hours, post-inj.	5½	24	48	1	6	24	48	6	24	48
Plasma inorg. P	1.20	.56	.42	10.15	2.58	1.06	.70	8.95	5.56	4.74
Biceps musc.	.14	.28	.15	.50	.23		.37	.32	.25	.16
Bile	.21	.78	.90	.30	.45		.70	.33	2.13	1.41
Brain	.03	.04	.05	.02	.04	.04	.04		.06	.11
Back Fat	.41		.35						.09	.81
Gastrocnemius musc.	.07	.25	.20	.25	.45	.27	.17	.20	.29	.28
Heart	.43	.36	.35	.55	.44	.55	.39	1.27	1.47	.72
Kidney	.51	.39	.46	1.18	.75	.55	.44	2.03	2.03	.84
Liver	.49	.47	.41	.75	.76	.64	.46	2.30	1.75	.88
Lung	.31	.35	.34	.37	.49	.43	.35	1.00	1.80	.60
Lymph node	.48	.39	.43		.49	.47	.36	1.09	1.17	.77
Ovary								1.31	.87	.80
Spleen	.32	.36	.32	.44	.55	.51	.39	1.14	1.26	.72
Stomach musc.	.20	.30	.34	.44	.42	.36	.17	.63	.55	.53
Thymus	.21	.37	.51	.33	.48	.44	.45	.89	.56	.80
Thyroid				.84	.47	.32			.96	
Tongue musc.	.27	.42	.29	.30	.51	.53	.38	1.00	1.35	.67

Since the animals used in these experiments varied considerably in body weight and injected dose of P^{32}, the specific activity was "standardized" for these variables, by representing the specific activity in terms of the original dose per unit body weight:

$$\text{Standard Specific Activity} = \frac{\text{Specific activity of the tissue}}{\frac{\text{mc } P^{32} \text{ injected}}{\text{Kg body weight}}}$$

A summary of the standard specific activities of the tissues analyzed is given in table 3.

Such a simple correction, however, does not make the data of different animals strictly comparable, since it would assume that they were in a similar physiological condition. This is obviously not correct, since the physiological processes of young and mature animals are quantitatively and qualitatively different. Thus, in order to compare the tissues of animals of different age, the specific activity of the tissue was represented in terms of the specific activity of the plasma inorganic phosphorus (the originally administered form, and ultimate precursor of all tissue phosphorus). On this basis, the data on homologous tissues are comparable, since the effect of other processes (such as bone development) is equal on the tissue and plasma inorganic phosphorus, and thus tends to cancel out. These results were called "Relative Specific Activity" and were calculated as follows:

$$\text{Relative Specific Activity} = \frac{\text{Specific activity of tissue}}{\text{Specific activity of Plasma Inorg. P.}}$$

The relative specific activities of some of the representative tissues are shown graphically in figure 1.

Discussion

It is evident from table 3 and figure 1 that there are large differences between the various tissues in their uptake rate (e.g., the extent of uptake during the period of the experiment) of plasma inorganic phosphorus. Some tissues, notably the liver and kidney, have a rapid uptake rate, whereas others, particularly the brain, have a much slower rate. The tissues can be arranged in a decreasing order of phosphorus uptake rate, the order varying slightly at different ages.

An "average" arrangement would be:

Bile, Liver, Kidney, Thymus, Lymph node, Spleen, Tongue muscle, Lung, Stomach (smooth) muscle, Gastrocnemius and Biceps (skeletal) muscle, and Brain.

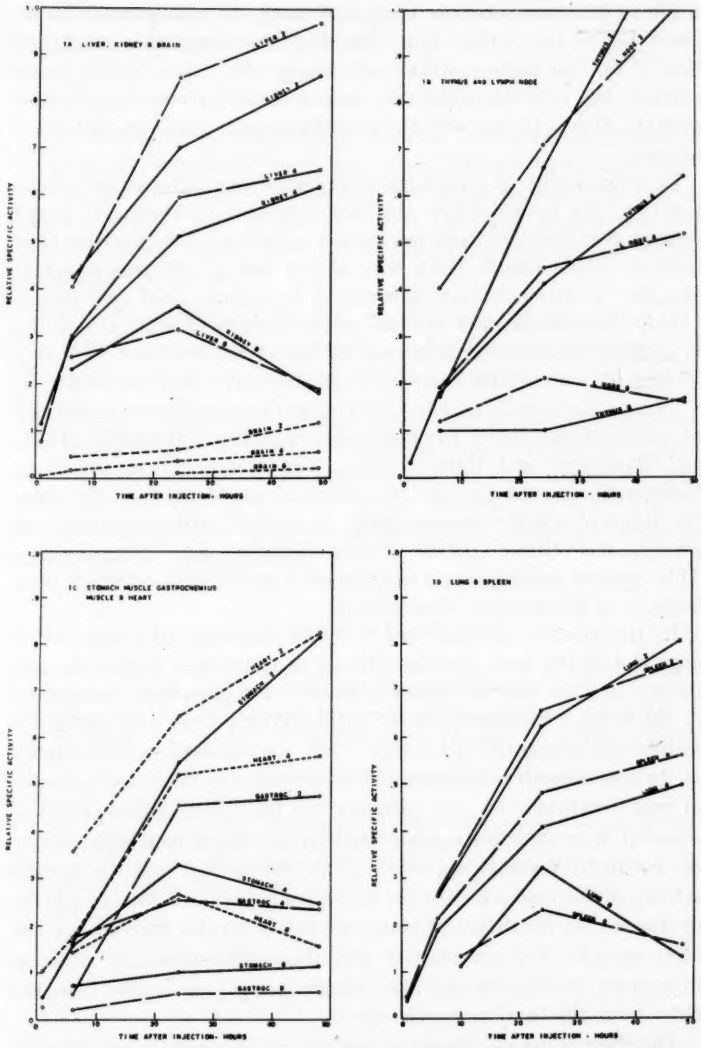

Figure 1. Relative specific activities of swine tissues of different ages (2, 4, and 8 months) following the intravenous injection of radioactive phosphorus (P^{32}).

Most of the tissues remain in approximately the same position on the above list at the various ages. The Thymus, however, is notable in that it has the highest uptake rate among the tissues in the young animals, but is hardly above the various muscles in the more mature animals. This is in line with the involution of the gland as the animal matures.

In other studies of phosphorus distribution soon after tracer administration, the tissues follow the above pattern generally. At longer periods after injection, however, there is a tendency for the series to be reversed. Thus, tissues which have a slow rate of phosphorus uptake also have a correspondingly slow rate of loss. Cook, Scott and Abelson (1937), for example, find that the specific activity of brain phosphorus in chicks is only two-thirds as great as that of the liver four days after feeding P^{32} but is three times as great sixty days after the feeding.

There is a pronounced effect of age on the phosphorus uptake rate of various tissues, which has been noted in rats by Falkenheim (1942) and Weisberger and Harris (1943). The nature of the age effect, however, is opposite for the two means of presentation of the data: the standard specific activity tends to increase with increasing age, whereas the relative specific activity decreases with increasing age. This apparent anomaly could be expected from the basis on which these methods of presentation were selected.

In the younger animals, much of the administered phosphate is deposited in the bone, leaving little to be distributed among the soft tissues. In older animals, however, little of the phosphate is deposited in the bone, consequently more of the injected dose is available for distribution among the soft tissues. Thus, the standard specific activity of the tissues tends to increase with increasing age. When the influence of bone formation (e.g., its "demand" on the incoming phosphate) is removed, as in the relative specific activity, the actual metabolic activity of the tissue becomes apparent. Thus, the greater relative specific activity of the tissues of younger animals indicates that the phosphorus uptake rate of the tissues of young animals is greater than that of the older animals. This corresponds with the general metabolic situation in animals of different age, the younger being more active than the older (viz., the basal metabolic rate).

The effect of age on phosphorus uptake rate is generally accompanied by a decreased phosphorus content of the tissues. In two cases, liver and brain, there seems to be a slight increase (not statistically significant). There is also a general increase in the dry matter of the tissues

with increasing age, the heart being an exception, showing a slight (not statistically significant) decrease.

Summary and Conclusions

The distribution of intravenously injected radioactive phosphate in the tissues of swine of different ages, and at different times after injection is reported. There is considerable variation between the various tissues regarding their uptake of plasma inorganic phosphorus. The tissues of swine can be listed in the following order of decreasing phosphorus uptake rate.

> Bile, Liver, Kidney, Thymus, Lymph node, Heart, Spleen, Tongue muscle, Lung, Stomach (smooth) muscle, Gastrocnemius and Biceps (skeletal) muscle, and Brain.

There is a considerable effect of age on the uptake of phosphorus by the tissues. Older animals have a slower rate of uptake (e.g., take longer to equilibrate with the plasma inorganic phosphate), but generally take up a greater portion of the administered dose. This is probably due to large quantities of phosphorus which are deposited in the bones of young animals.

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VALUE OF LOW- AND HIGH-FAT CORNS FOR FATTENING HOGS

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HYBRID varieties of corn have been developed which contain comparatively high levels of fat. In some cases the increased fat content is accompanied by an increase in crude protein content. The relationship between firmness of the body fat of hogs and the character and composition of the ingested fat has been reported by Hankins and Ellis (1926), Ellis and Isbell (1926) and Bull *et al.* (1931). Vestal and Shrewsbury (1944) studied the value of hominy feed in rations for fattening swine and found that even hominy feed with a fat content of 5 percent, the lowest tested, produced some soft carcasses when it was fed to replace all of the corn in the rations.

The experiment reported herein was conducted to compare the feeding value of yellow corns containing 4.7% and 6.4% fat (dry basis) for growing-fattening hogs and to study the effect of the increased fat content of the corn on carcass quality.

Experimental Procedure

Thirty pigs averaging about 101 pounds in weight were allotted to two groups and were self-fed shelled yellow corn and a mixed supplement on winter rye pasture to an average final weight of 226 pounds. Each pig was allotted and transferred to this test from a dry-lot growing-fattening test (weaning to 100 pounds) on the weigh day that it reached a final weight of approximately 100 pounds. In lot 1, shelled yellow corn containing 4.7% fat and 9.0% crude protein (dry basis) was self-fed free-choice with a mixed supplement composed of 100 pounds meat and bone scraps, 100 pounds expeller soybean oil meal, 100 pounds dehydrated alfalfa meal, 9 pounds vitamin B_{12} and

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antibiotic feeding supplement,[1] 3 pounds ground limestone, 3 pounds steamed bone meal, and 6 pounds iodized salt. In lot 2, shelled yellow corn[2] containing 6.4% fat and 10.8% crude protein (dry basis) was self-fed free-choice with the same mixed supplement fed in lot 1. Each pig was removed from test on the weigh day that it weighed approximately 225 pounds.

The carcasses from all hogs that were slaughtered were held in a cooler at 32° F for 40 hours before they were scored for carcass grade and firmness. At this time cold weights, carcass measurements and fat samples were taken. Carcass firmness grades (organoleptic method) were determined when the internal ham temperature was 34°–36° F. A 1″ x 6″ sample of back fat over the lumbar region was obtained by a method similar to that used by Bull *et al.* (1931). Hankins and Ellis (1926) reported that body fat is more representative of carcass firmness than leaf fat. At the close of the test a refractive index determination was made on each fat sample. The fat samples were rendered at 115° C. in an electric oven for 4 hours. The refractive index of the rendered fat was determined by means of an Abbé refractometer. Iodine number analyses (Hanus method) were made after unrendered fat samples had been stored for 2 months at 0° F and then rendered. Shrewsbury *et al.* (1942) concluded that there was no significant change in the saturation of the fat as measured by refractive indices or iodine numbers from either firm or soft carcasses with increase in time of storage.

The data in this test were analyzed statistically using the t-test for unpaired differences.

Results and Discussion

The results presented in table 1 show that the average daily gains of the two lots of pigs did not differ significantly. The total feed eaten per unit of gain and the average daily feed per pig were quite similar for both lots of pigs. It may be observed that the pigs in lot 2 receiving the higher fat corn, which was also higher in protein consumed 27% less mixed supplement, and 3% more corn per unit of gain than did pigs in lot 1. Dobbins *et al.* (1950) in comparing corns varying in crude protein content reported that 9.1% protein corn (10.9% crude protein on a dry basis) satisfactorily replaced 27.8% of the protein supplement in a mixed ration for pair-fed pigs over 100 pounds in

[1] Donated by Lederle Laboratories Division, American Cyanamid Co., Pearl River, through the courtesy of Dr. T. H. Jukes. This was an aureomycin fermentation product (Lederle APF-5).
[2] Purchased from Funk Bros. Seed Co., Bloomington, Illinois.

weight when compared with 7.7% protein corn (9.1% crude protein on a dry basis).

Carcass data on the 21 barrows that were slaughtered are summarized in table 2. There were no statistically significant differences between lots for any of the items listed in table 2. The carcass quality as measured by the carcass grade and carcass firmness (organoleptic

TABLE 1. EFFECT OF LOW- AND HIGH-FAT CORN ON RATE AND EFFICIENCY OF GAINS OF GROWING-FATTENING HOGS

(Experiment Began Dec. 28, 1949)

Items compared	Lot 1 low-fat corn[1]	Lot 2 high-fat corn[2]
(Each lot was self-fed shelled yellow corn and supplement,[3] free choice and had access to ½ acre of rye pasture)		
Number of pigs	15[4]	15
Average initial weight, lb.	100.9	100.7
Average final weight, lb.	226.0	225.8
Average daily gain, lb. and standard error	1.61±.05	1.58±.04
Average daily feed		
Shelled yellow corn, lb.	5.99	6.09
Supplement, lb.	0.64	0.46
Total, lb.	6.63	6.55
Feed eaten per 100 lb. gain		
Shelled yellow corn, lb.	376.7	388.2
Supplement, lb.	40.0	29.3
Total, lb.	416.7	417.5

[1] Contained 4.7% fat and 9.0% crude protein on a dry basis or 4.1% fat and 7.7% crude protein on a fresh basis.

[2] Contained 6.4% fat and 10.8% crude protein on a dry basis or 5.3% fat and 9.0% crude protein on a fresh basis.

[3] Consisted of 100 lb. meat and bone scraps (50% crude protein), 100 lb. expeller soybean oil meal, 100 lb. dehydrated alfalfa meal, 9 lb. aureomycin fermentation product, 3 lb. ground limestone. 3 lb. steamed bone meal and 6 lb. iodized salt and by analysis contained 92.2% dry matter, 5.9% fat and 39.4% crude protein.

[4] One unthrifty pig removed from lot 1 soon after the test began.

measurement) showed only slight differences. The most accurate methods of measuring the actual degree of unsaturation of the fat are the iodine number and refractive index determinations. Fat samples from hogs fed the higher fat corn (lot 2) had an average iodine number of 65.81 as compared with 63.84 for fat samples from hogs fed the low fat corn (lot 1). This difference was not statistically significant (odds 10:1).

Under the conditions of this test there appeared to be no disadvantage

to feeding the higher fat corn from the standpoint of carcass quality or rate and efficiency of gain. In producing 100 pounds of gain, 100 pounds of the high-fat corn replaced 97.0 pounds of lot-fat corn plus 2.8 pounds of mixed supplement.

Summary

Two lots of 15 pigs each were self-fed shelled yellow corn and mixed supplement on winter rye pasture from an average initial weight of 101 pounds to an average final weight of 226 pounds to study the effect on carcass quality and rate and efficiency of gain of feeding corn containing 4.7% fat and 9.0% crude protein as compared with corn containing 6.4% fat and 10.8% crude protein (analyses on a dry basis). No significant differences occurred between the two groups in rate of gain, dressing percentage, carcass grade, carcass firmness grade, backfat thickness and refractive index of body fat. Fat samples from hogs fed the higher fat corn had an average iodine number of 65.81 as compared with 63.84 for fat samples from hogs fed the low-fat corn (odds 10:1). The total feed eaten per 100 pounds gain was practically the same for each group, but the pigs receiving the higher fat corn, which was also higher in crude protein, consumed 27% less mixed supplement per unit of gain.

TABLE 2. EFFECT OF LOW- AND HIGH-FAT CORN ON CARCASS QUALITY IN HOGS

Items compared	Lot 1 low-fat corn	Lot 2 high-fat corn
Number of pigs slaughtered	10	11
Average live weight, lb.	224.8	226.1
Average cold dressed weight, lb.	181.0	179.6
Average dressing percentage[1]	80.5±.4	79.6±.4
Average carcass grade[2]	1.4±.2	1.4±.2
Average carcass firmness grade[3]	2.4±.5	2.1±.3
Average backfat thickness,[4] cm.	4.74±.21	5.19±.13
Fat samples		
Average refractive index	1.4604±.00004	1.4603±.00004
Average iodine number	63.84±1.08	65.81±.21

[1] Dressed shipper style. Standard error given for all remaining items.
[2] Numbers assigned carcass grades are as follows: Choice No. 1, 1; Choice No. 2, 2; and Choice No. 3, 3.
[3] Numbers assigned to carcass firmness grades are as follows: Hard, 1; medium hard, 2; medium soft, 3; and soft, 4.
[4] Backfat thickness was measured at the 1st thoracic, 13th thoracic and 1st sacral vertebrae.

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EFFECTS OF ELEVATED AMBIENT TEMPERATURE ON PREGNANT SOWS[1]

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THIS paper is one of a series concerned with the effect of climatic factors on swine (Heitman and Hughes, 1949; Kelly, Heitman and Morris, 1948). The investigation herein reported is concerned with the effects of increased ambient (environmental) temperature, and the subsequent increase in body temperature, on pregnant sows using the California Psychrometric Chamber previously described by Heitman, Kelly, and Hughes (1949).

Experimental

Experiments are reported on thirteen pregnant sows. They were brought into the psychrometric chamber in pairs. The only selection practiced was for stage of gestation. They were at least 85 days pregnant. All had been maintained at the swine barn under good practical conditions, including pasture when available. Management in the psychrometric room has been previously described (Heitman and Hughes, 1949). Body weights varied from about 300 to 560 pounds at the beginning of the experiment as indicated in table 1. Four breeds were represented, and animals varied from gilts in first gestation to sows carrying their fourth litters.

Balanced rations were fed according to the recommendations of the California Experiment Station (Hughes and Heitman, 1949) for gestating swine. These were based on barley, tankage, soybean oil meal, alfalfa meal, wheat bran, oystershell flour and common salt.

The ambient temperature of the chamber was about 70° F. and the relative humidity approximately 50% when the sows were started on the experiment. The relative humidity varied from 40 to 60% during the trials. The temperature was increased by 5 to 10° steps until there was a definite body (rectal) temperature rise. This increased ambient temperature was maintained when possible for 24 to 72 hours unless the body temperature of the sow indicated that this was not feasible and death might result. The ambient temperature was then dropped to about 75° F. for a few hours and the sows returned to the swine barn.

[1] This paper is a result of a cooperative project between the Division of Farm Buildings and Rural Housing, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Dept. of Agriculture, and the Divisions of Animal Husbandry and Agricultural Engineering of the University of California.

[2] Division of Animal Husbandry, Davis, California.

[3] U. S. Department of Agriculture. Now with: Division of Agricultural Engineering, University of California, Davis, California.

TABLE 1. REACTIONS OF PREGNANT SOWS TO INCREASED AMBIENT TEMPERATURE[3]

Sow No.	Days of Gestation[1]	Initial Body Weight (lbs.)	Loss in Body weight (lbs.)	Maximum Daily Ambient Temperature (°F.)	Highest Daily Body Temperature[6] (°F.)	Highest Daily Respiration[6] (per minute)	Days Body Temperature over 104° F.
H324	77–93	303	33	97	105.2	147	13
B205	87–96	470	44	99	104.6	124	3
P326[2]	88–98	347	37	97	107.7[2]	143	9
H320	92–99	408	22	97	104.6	148	2
D5	92–99	536	12	95	103.7	135	0
B316	93–100	420	24	97	104.9	144	3
P318[3]	97–104	408	7	89.5	101.9	104	0
D145	98–105	558	20	95	105.3	182	1
H201	99–107	406	20	93.5	104.3	181	3
H210	99–107	542	42	98	105.0	186	3
H211	99–108	434	36	99	104.8	152	3
H115	102–110	472	28	93.5	104.8	184	3
B1[3]	106–114	337	4	89.5	102.0	136	0
Average[4]			28.9[5]	96.5	105.0	156.9	3.9

D=Duroc; B=Berkshire; P=Poland China; H=Hampshire.

[1] Stage of gestation while in psychrometric chamber.

[2] Died on 98th day of gestation. Body temperature immediately following death approximately 113° F.

[3] P318 aborted as explained in text on 103rd day of gestation. B1 was in chamber with P318. Ambient temperature never above 89.5° F. Since maximum temperature was relatively low, figures not included in averages.

[4] For 11 sows (P318 and B1 are not included).

[5] Equivalent to a weight loss of about 3.3 lbs. per day per sow.

[6] Initial body temperature ranged from 100.6 to 102.4° F. and averaged 101.2° F. Initial respiratory rate ranged from 24 to 37 per minute and averaged 29. These ranges and averages exclude those on H324 and P326 because the initial ambient temperature was 86° F. In other cases initial ambient temperatures ranged from 67–76° F.

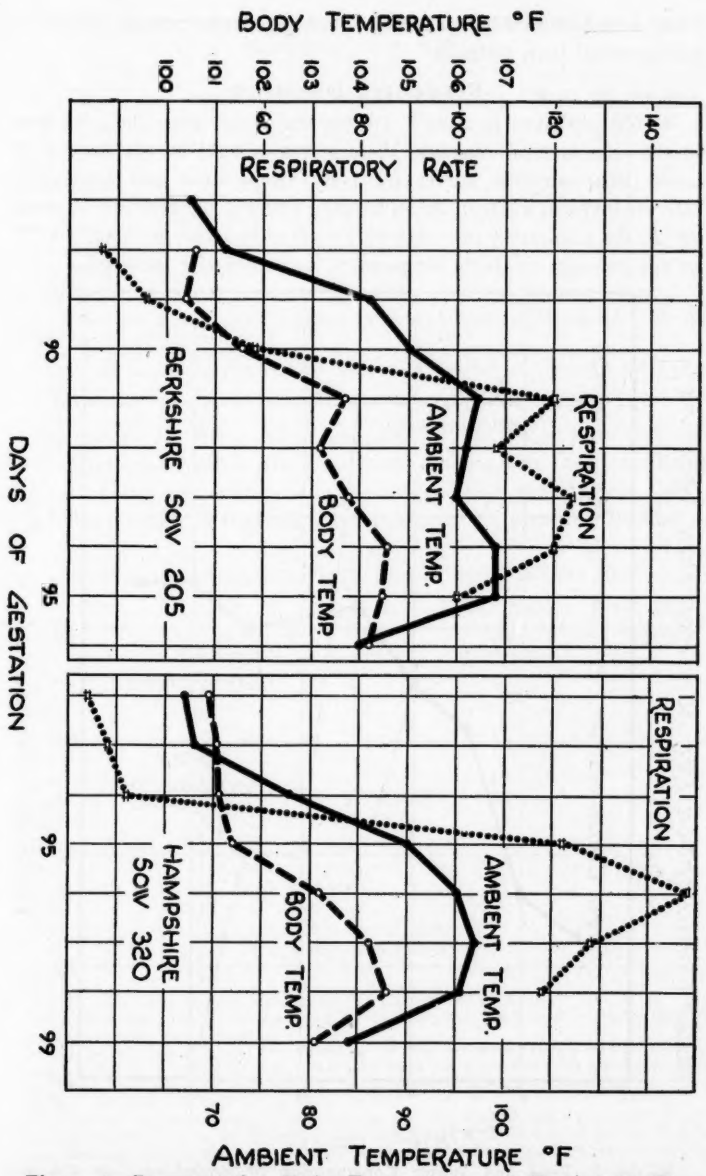

Figure 1. Representative Body Temperature and Respiratory Rate Curves of Pregnant Sows Exposed to Increased Ambient Temperatures.

They were farrowed out and raised their pigs under normal conditions and practical barn methods.

Results and Discussion

Results are given in table 1. During the period when the sows were in the experimental chamber, there was a general weight loss in all cases. Representative curves for body temperature and respiratory rate are given in figure 1. At an average ambient temperature of about 88° F. the respiratory rate showed a marked increase. At about 94° F. on the average, the body temperature was markedly increased.

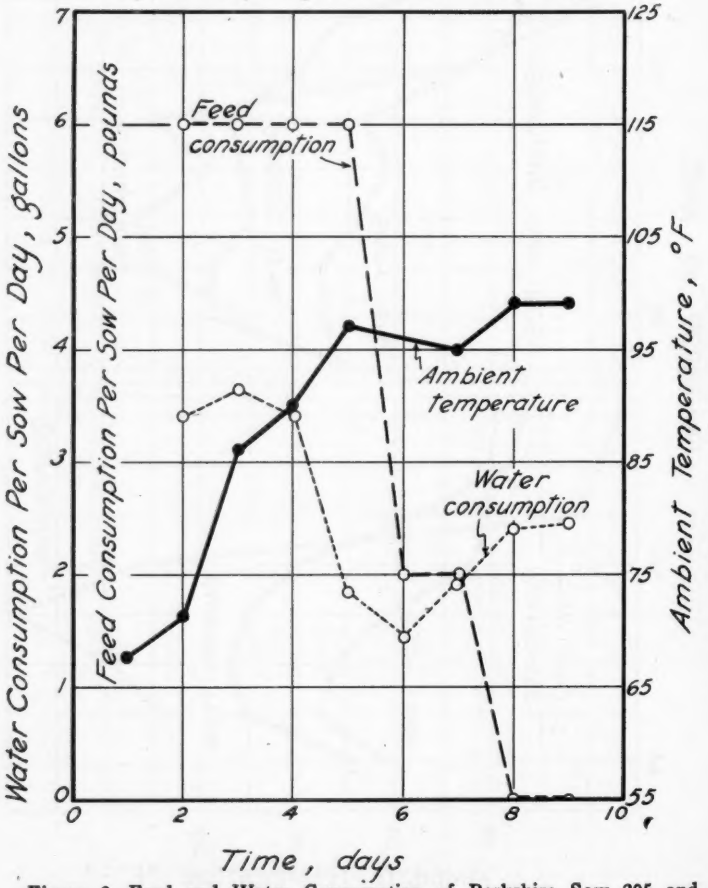

Figure 2. Feed and Water Consumption of Berkshire Sow 205 and Hampshire Sow 211.

TABLE 2. FEED AND WATER CONSUMPTION OF EXPERIMENTAL SOWS

Sow Nos.[a]	Feed per sow per day (lbs.)	Water per sow per day (gals.)
P326, H324	1.15	1.75
H324[b]	.25	1.42
H115, H201	1.87	1.47
B318	5.25	2.36
D5, D145	3.33	1.76
B205, H211	3.75	2.35
H320, B316	4.07	2.35
H210, D165[c]	2.00	1.73

[a] Two sows were in the chamber at a time. Figures are averages for the two as both ate and drank from common troughs.

[b] This is for the period after P326 died. H324 was already at ambient temperature of 94° F.

[c] D165 was an open sow. Figures here, therefore, are average of a pregnant and a non-pregnant sow.

Part, if not all, of the weight loss probably was due to a lowered feed and water consumption which has been found under these conditions where ambient temperature is increased (Heitman and Hughes, 1949). The average data on feed and water consumed are presented in table 2.

TABLE 3. FARROWING DATA FOR EXPERIMENTAL SOWS

Sow No.	Length Gestation, Days	Total No. Pigs Farrowed	No. Live Pigs Farrowed	No. Pigs Weaned
B1	117	7	5	4
B205	117	4[a]	3	3
B316	117	15	11	6
D5	113	14	11	8
D145	113	13	10	7
H115	112	11	10	9
H201	113	11	11	8
H210	113	11	10	8[b]
H211	112	8	8	7
H320	115	10	10	9
H324	113	9	9	4
P318	aborted on 103rd day of gestation.[c]			
P326	died on 98th day of gestation.[d]			
average	114.1	10.3	8.9	6.6

[a] Three other litters from this sow averaged 10.3 pigs farrowed per litter.

[b] This litter was raised on concrete for an anemia experiment. The loss of one of the pigs was probably due to his anemic condition.

[c] Two fetuses appeared normal even though one of these was small. There were two fetuses of good size starting to be resorbed. Five fetuses were small and mummified. This sow had farrowed one normal litter prior to this aborted one. She subsequently produced two more normal litters. She was negative to Brucellosis and in a negative herd.

[d] There were 8 normal fetuses in the uterus of this sow at death and one mummified one. Autopsy was performed by the Division of Veterinary Science, and the opinion was expressed by them that there were no signs of death of the litter an appreciable time before that of the dam. Death was attributed to heat prostration.

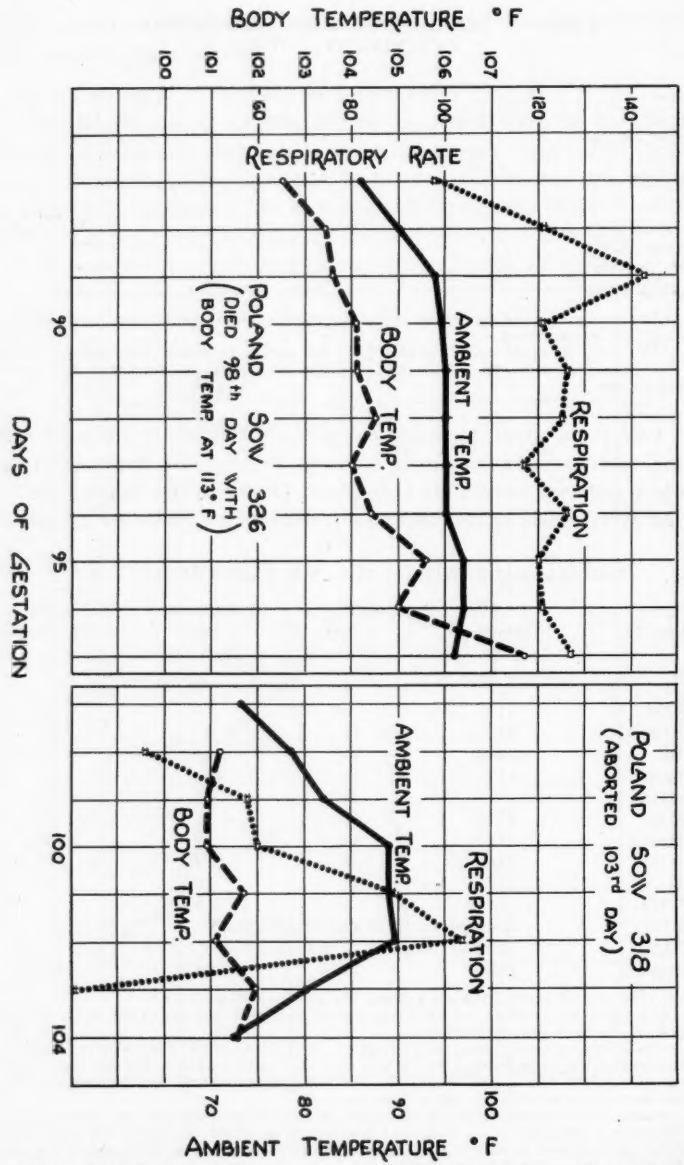

Figure 3. Body Temperature and Respiratory Rate Curves for Poland Sows 326 and 318.

It will be noted that the daily feed consumption runs quite low, about 50% of normal expectation. Figures in table 2 are averages for the complete experimental periods. In figure 2 representative curves for daily feed and water consumption are plotted for one experiment. Farrowing and weaning data are given in table 3. Eleven of the thirteen sows farrowed normally. The number of pigs weaned appeared to be practically normal. While the results in some instances could have been better, it is difficult to attribute any of them to the increased ambient temperature. Exception to this might be made in the case of H324. Her litter was not thrifty, and she did not milk well.

As shown in tables 1 and 3, P326 died of heat prostration on the 98th day of gestation after 10 days on experiment and with a rectal temperature of 107.7° F. the day preceding death. She died while trying to arise when the attendant entered the chamber in the morning to make his observations. Immediately following death her rectal temperature was 113.0° F. Autopsy was performed within an hour and 8 normal fetuses were found as well as a mummified one. Apparently the litter death did not antedate that of the dam. Reactions of P326 are graphically presented in figure 3.

P318 aborted her litter on the 103rd day of gestation as indicated in tables 1 and 3. Her responses are plotted in figure 3. It will be noted that the ambient temperature never exceeded 89.5° F. while this sow was in the chamber and the rectal temperature was relatively low. There were nine fetuses aborted of which only two appeared normal, and one of these was quite small. There were two good sized fetuses in the initial stages of resorption, and the five remaining ones were small and mummified. It cannot be stated whether or not the experimental procedure caused the abortion, but at least the majority of the litter was undergoing resorption prior to the sows entry into the chamber six days before abortion. The herd to which she belonged was negative for Brucellosis. She had produced one normal litter and subsequently has produced two more normal litters.

One open sow (D165) was subjected to increased ambient temperature along with a pregnant animal (H210). Figure 4 shows the difference in body temperature response. D165 showed a minimum respiratory rate of 64 per minute at an ambient temperature of 98° F. whereas the respiratory response of H210 (pregnant) went as high as 186. The body weights of these two sows were within 20 pounds of each other while in the chamber. Results with the open sow indicated that the ambient temperature used in these studies did not distress her as much even though she lost 33 pounds during the 8-day experiment, and her

feed and water consumption (table 2) appears to have been about the same as that of the pregnant animals.

As evidenced by the rise in respiratory rate followed by the one in body temperature, and compared with the results obtained with the open sow (D165) it would appear that under these conditions the pregnant animal (H210) had difficulty dissipating the heat caused by

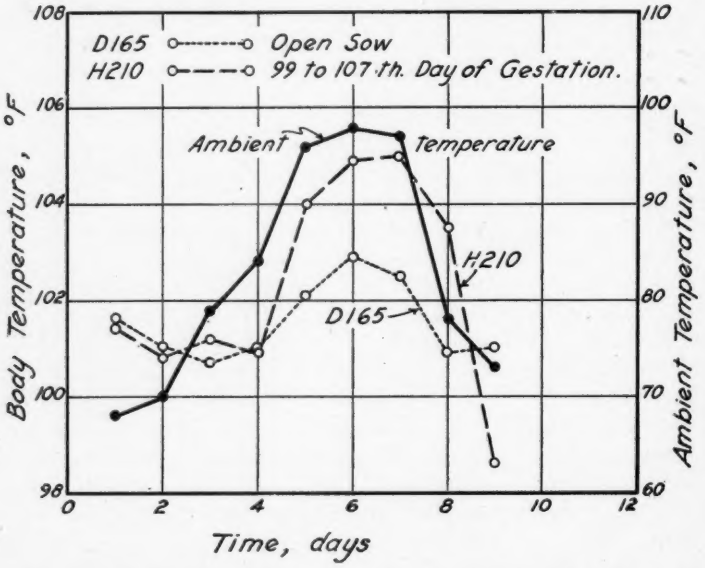

Figure 4. Body Temperature Curves for Duroc Sow 165 (open) and Hampshire Sow 210 (pregnant).

the additional "metabolic load" of her litter. However, results obtained from the sows that farrowed, as well as the one that died of heat prostration, indicate that in swine a high environmental temperature (and subsequent high body temperature) apparently will kill the dam before it will cause death of the litter and subsequent abortion.

It has been reported by Ragsdale and associates (1948) that two dairy cows aborted 4½ and 6 month fetuses when exposed for 27 hours to a temperature of 100° F. Possibly this is an indication of a species difference.

Summary

Results are reported on the reactions of 14 sows to ambient temperatures ranging as high as 99° F. Thirteen were 85 or more days pregnant and one was open. Increasing the ambient temperature elevated markedly the respiratory rate and body (rectal) temperature of the pregnant swine. Feed and water consumptions were lowered. Of the 13 pregnant sows, 11 successfully farrowed following their return to normal conditions after being under experiment for periods averaging 8 days.

During these experimental periods, they were exposed to high temperatures for 24 to 72 hours. The 12th sow died from heat prostration carrying a litter which was apparently normal. The remaining sow aborted, but the majority of her litter gave evidence that it was undergoing resorption before the experiment was started. No evidence was accumulated that indicated that rise in body temperature under these conditions would cause abortion of a normal litter. The open sow lost weight and had a lowered feed and water consumption comparable to the pregnant sows. However, her respiratory and body temperature responses were much less pronounced.

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THYROTROPIC-HORMONE DEFICIENCY IN HOMOZYGOUS DWARF BEEF CATTLE[1]

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THE phenotypic expression of hereditarily conditioned dwarfism in beef cattle has been described by the authors in a separate paper (1951). Johnson *et al.* (1950) described this hereditary dwarfism for the first time. People who have had experience with these dwarfs are able to recognize them at birth. The dwarf calf is low-set, compact, blocky, short in the neck, wide through the body and has a broad, short face—in other words, he shows much promise of becoming an outstanding individual. Studies of the head contour have shown that the dwarf has a marked mid-forehead prominence present at birth which persists throughout life. The head is brachycephalic, the mandible is misshapen, exhibiting prognathism, and the incisors usually extend forward to the dental pad from one-half to three and one-half centimeters. When the dwarf becomes three or four months of age, it appears stunted, pot-bellied, and breathes heavily. Not many live to be more than two years old and death from bloat is common. Autopsies and histological studies have revealed little.

This report is part of a physiological study undertaken to determine what causes the dwarfism. It is well to mention the studies made on hereditarily conditioned dwarf mice by Smith and MacDowell (1930, 1931). Their interesting work showed a lack of eosinophiles in the anterior pituitary, and deficient adrenals and thyroid which could be restored by pituitary implants from normal rats. The dwarf mouse pituitaries were deficient in the production of ACTH and thyrotropic hormone and apparently growth hormone. Hereditary cretinism, another form of dwarfism, has been reported in man and animals (Fagge, 1871; Crew, 1924; Liddell, 1925; Landauer, 1929; Seligmann, 1904). The morphological changes described in these reports and those observed in experimental thyroidectomized animals (Dye and Maughan, 1929; Todd and Wharton, 1939; Dye and Kinder, 1934; Spielman *et al.*, 1945) are similar to those found in dwarf calves used in this study.

According to Freeman (1948) "cretinism is a condition of hypothy-

[1] This work was supported by the Kellogg fund for the application of genetics to farm mammals. The study was in cooperation with the Bureau of Animal Industry, U.S.D.A. and the state experiment stations under Western Regional project W-1 on beef cattle breeding research.
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roidism occurring in fetal life or early infancy. Its cause is at present uncertain but may in some cases be due to an insufficient amount of thyrotropic pituitary hormone." The data submitted in this report show that the pituitaries from the dwarf calves studied are deficient in thyrotropic hormone.

Materials Used

For the most part, the dwarf cattle used in this study were Hereford calves. These animals were obtained from breeders in this state, who have been most cooperative. Contact with the breeders was facilitated by members of the University of California Extension Service, particularly the livestock specialists and county farm advisors. The dwarf calves were taken to a local slaughter house, and the pituitary glands were obtained within 30 minutes from the time the animals were bled. The pituitaries were promptly placed in ice containers and kept in the frozen state until used. Pituitaries from normal animals were also obtained.

The method used for assaying the thyrotropic hormone content of the pituitaries was that of Smelzer (1937) as modified by Elijah and Turner (1942). The pituitaries were trimmed, weighed, macerated in a tissue grinder, and suspended in sterile saline. Merthiolate was used as a preservative. One ml. of suspension contained 100 mg. of pituitary tissue. One-day-old white Leghorn cockerels were purchased from a local hatchery which maintained its own purebred laying flock. For an assay, 3 groups of cockerels were used: a control group, a second group to receive injections of normal pituitary tissue, and a third group to receive injections of pituitary tissue from dwarf calves. Groups 2 and 3 were subcutaneously injected with 0.05 ml. of pituitary suspension each day for 4 days (a total of 20 mg. of pituitary tissue for each bird). Twenty-four hours after the last injection, the birds were sacrificed and the thyroid glands dissected and weighed.

The work of Bergman and Turner (1939) indicates the most sensitive range for the assay of thyrotropic hormone is obtained when the chick thyroid weight is less than 8 mg. In a series of assays, tabulated in table 1, all of the thyroid weights fell within this sensitive range.

Results

The assays A, B, and C (table 1) were made first and the results were statistically analyzed (table 2). The non-significance of assay differences and of the interaction term indicates that the experimental

TABLE 1. AVERAGE THYROID WEIGHTS IN MILLIGRAMS OF CONTROL AND EXPERIMENTAL COCKERELS

Assay		Controls	Normal Pituitary	Dwarf P Pituitary
A	Number	11	10	7
	Average	3.33	6.30	3.69
B	Number	20	20	20
	Average	3.88	5.76	4.33
C	Number	21	20	20
	Average	3.59	5.57	4.19
D	Number	20	—	18
	Average	3.42		3.30
E	Number	21	—	21
	Average	3.78		3.88
TOTAL	Number	93	50	86
	Average	3.63	5.79	3.92

materials and techniques were reasonably under control. The highly significant differences between treatment means were further analyzed. An unbiased estimate of the average thyroid weight of cockerels receiving dwarf pituitary injections was found to be 0.50 mg. greater than that for controls. This difference is significant at the 5 percent level of probability.

The average thyroid weight of cockerels injected with normal pituitary tissue was estimated to be 1.62 mg. greater than for those injected with dwarf pituitary tissue. This difference is significant at the 1 percent level of probability. Ninety-nine percent confidence limits for this difference are 1.00 mg.—2.24 mg. These results indicate that the

TABLE 2. ANALYSIS OF VARIANCE OF THYROID WEIGHTS OF COCKERELS DESCRIBED IN TABLE 1.

(Method of Expected Subclass Numbers)[1]

Source of Variation	Degrees of Freedom	Mean Square
Between assays	2	0.766
Between treatments	2	62.307**
Interactions	4	1.583
Within groups	140	1.384

[1] Snedecor (1946).
** $P<0.01$.

pituitaries from dwarf beef cattle are quite deficient in thyrotropic hormone.

In subsequent assays D and E, further comparisons were made between the average thyroid weights of controls and those of cockerels injected with dwarf pituitary tissue. Combining these latter results with

TABLE 3. SOURCE OF PITUITARIES USED IN THE ASSAYS AND THEIR THYROTROPIC HORMONE CONTENT IN CHICK UNITS

Assay	Animals Used[1]	No.	Age	Ave. weight lbs.	Ave. pituitary wt. (fresh)	Ch. U.[2] Per Pituitary
A	Normal Steers	3	2 yrs.	1050	1.60 gm.	142.5
	Dwarf calves					
	2 bulls	4	4–6 mos.	195	.57	6.2
	2 heifers					
B	Normal calves					
	1 bull	3	4–6 mos.	325	1.10	53.4
	2 heifers					
	Dwarf calves					
	1 bull	3	4–6 mos.	185	.49	5.7
	2 heifers					
C	Normal calves					
	1 bull	3	6 mos.	400	1.20	66.1
	1 heifer					
	1 steer					
	Dwarf calves					
	1 bull	2	6 mos.	200	.90	15.1
	1 heifer					
	dwarf steer	1	2 yrs.	400		
D	Dwarf calves					
	1 bull	2	5 mos.	200	.84	none
	1 heifer					
E	Dwarf bull calf	1	6 mos.	170	.53	1.4

[1] All animals used in these assays were Herefords.

[2] Chick unit (male) is the total amount of hormone administered over a 4-day period, with subcutaneous injections once each day, which will cause a mean weight increase of 50 percent in the thyroids of 20 chicks weighing an average of 55±10 gms. (Bergman and Turner, 1939).

those from the former assays A, B, and C, the average thyroid weight of cockerels injected with dwarf pituitary tissue was estimated to be 0.29 mg. greater than that of the controls. This difference is significant at the 5 percent level of probability. Hence, the experimental evidence indicates that the pituitary glands of these dwarfs probably do contain thyrotropic hormone, but certainly to a much lesser extent than do the pituitaries of normal beef animals.

Table 3 gives the weights of the pituitaries used in the thyrotropic hormone assay (table 1). All of the dwarf animals studied had smaller pituitaries than normal animals of comparable age.

Discussion

The results show that pituitary tissue from dwarf beef cattle caused chick thyroid glands to increase in weight over those of controls. The increase was significant at the 5 percent level. Pituitary tissue from normal beef cattle, however, caused a much greater increase in thyroid gland weight. These results indicate the pituitaries from dwarf beef cattle to be deficient in thyrotropic hormone. The extent of the deficiency might account considerably for the failure of these dwarf calves to grow as large as normal calves. Further studies in this laboratory indicate the presence of growth hormone in the dwarf calf pituitary. Likewise, it was found that dwarf calf pituitary caused as much gonad stimulation as normal pituitary.

Summary

Physiological studies have been undertaken to determine why hereditarily conditioned beef cattle dwarfs fail to grow. Results were obtained which indicate the pituitary glands are deficient in thyrotropic hormone. This deficiency might largely account for the dwarfism. Additional data indicate that the growth hormone in the dwarf pituitary as well as gonad stimulating hormone are present.

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A PHENOTYPIC EXPRESSION OF HOMOZYGOUS DWARFISM IN BEEF CATTLE[1, 2]

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A NEW type of hereditary dwarfism in cattle unlike any heretofore reported has been described by Johnson, Harshfield, and McCone (1950). Afflicted individuals can be recognized at birth by those familiar with the condition. Heifers with a dwarf calf at the first delivery are predisposed to dystocia. Johnson *et al.* attribute this difficulty to a slightly greater body width which they say is characteristic of the dwarf. They note furthermore that dwarfs may have slightly bulging foreheads, but this alteration is not extreme and may not be present. In general, the more apparent symptoms are progressive and become increasingly pronounced with age. By three or four months the paunch becomes distended; after that the tendency to chronic bloat is marked.

Post-natal mortality is high, and only a few live to maturity. One female came in heat before she died of bloat at two years of age. Autopsies of young animals reveal little. In one ten-day old calf that had never stood, the flexor tendons of the legs were contracted, and the lateral ventricles of the brain contained more than the normal amount of fluid. Autopsies were performed on two older calves, both of which had been subject to chronic bloat for several months. One had died from bloat, and the other was slaughtered for autopsy. A rumen greatly distended with gas was the outstanding anomaly; there was no evidence of gross lesions. Histological sections of pituitary,

[1] This work was supported by the Kellogg Fund for the application of genetics to farm mammals.

[2] A part of the cost of the illustrations was borne by a grant by Mr. C. M. Goethe.

[3] Since the data were collected in the field, the authors are deeply indebted to a great many people. Although they prefer to remain anonymous, breeders of all the three breeds involved gave their time and helped in every way possible to make this study a success. The interest, aid, and cooperation given by various personnel of some of the breed associations were most helpful. We are obligated to Professor E. B. Stanley and Mr. O. F. Pahnish of the University of Arizona for permitting us to measure the dwarfs they were investigating. Entree to most of the dwarfs studied from California herds was obtained through the University of California Agricultural Extension Service. This was made possible by the genuine interest of Director of Agricultural Extension, J. Earl Coke, Director of Programs J. J. McElroy, and Extension Animal Husbandmen Reuben Albaugh and H. T. Strong. The Farm Advisors in all the counties in which studies were made were most cooperative. We are especially obligated to Mr. R. C. Geiberger, Farm Advisor of Sacramento County. In the laboratory we were most fortunate in having the assistance of Mrs. Ruth Skolil.

[4] Davis, California. This study was in cooperation with the Bureau of Animal Industry, U.S.D.A. and state experiment stations under Western Regional Project W-1 on beef cattle breeding research.

thyroid, and adrenals failed to disclose anomalies in these glands. Study of the genital tract of the male showed little spermatogenesis, but spermatozoa were found in the sections of the ampulla and the ductus deferens.

The authors present evidence indicating that the diminutive is conditioned by a single autosomal recessive gene. What is more significant, they suggest that heterozygotes may be favored in the selection of breeding stock, thus causing a marked increase in the frequency of the conditioning gene in the population.

It is unnecessary to review the literature of lethal genes in cattle. Those interested may consult the check list compiled by Lerner (1944). It should be emphasized that the dwarf described by Johnson *et al.* is unlike other dwarf types reported in the literature. It should never be confused with the proportionate dwarfism of Jerseys reported by Mead *et al.* (1942). Those dwarfs were not recognizable until about a year of age, at which time they were perceptibly smaller than normals of the same age, the adult weight being approximately 750 pounds and reproduction and lactation being normal. The dwarf called "Stumpy" reported in Shorthorns by Baker *et al.* (1950) is characterized by a general unthriftiness, achondroplasia, and a short tail. Since all manifest a curly coat, diagnosis at birth is easy. The condition is not lethal, and reproduction is normal.

This paper is the first of a series from our laboratory concerning the type of dwarfism described by Johnson *et al.* While the authors of this paper knew of the existence of this problem earlier, they did not begin a study of it until the fall of 1949. At that time several California breeders reported the occurrence of dwarfs in their herds of registered cattle and requested assistance in control. The breeds involved are Hereford, Angus, and Shorthorn, the first breed mentioned having supplied the major portion of the data used in this study.

Our studies of inheritance involve several herds and a few hundred animals. The hypothesis that a single autosomal recessive gene conditions the dwarfism is tenable and confirms the conclusions of Johnson *et al.* Penetrance is complete. Even though they lacked critical data to prove that the heterozygote was favored in selection, several things about their observations led them to suspect this was the case. In January of 1950, the authors of this paper, also suspecting that individuals heterozygous for dwarfism were favored as breeding stock, adopted this as a working hypothesis. Most of our investigations have been directed to the accumulation of critical data to prove or disprove this hypothesis. It has been assumed that if the nature of phenotypic

expression of dwarfism is clearly comprehended in the homozygous state, any manifestations of the dwarf gene in the heterozygous state can be more easily recognized.

Our observations of the phenotypic expression of the dwarf gene in the homozygous condition are in general agreement with Johnson *et al.*, yet there are certain characteristics they do not mention and others they mention that merit amplification. This paper will deal exclusively with the two types of homozygotes, normal and dwarf.

Source and Collection of Data

The data used in this study were collected both from herds of California breeders and from those in other states. All measurements and the collection of data in the field were taken by or under the direct supervision of one of us (PWG). The general practice was for two to work together in the field. The data collected on each dwarf included date of birth, sex, identity of sire and dam, and owner; body measurements taken were weight, height at withers, height at hooks, height of hock, heart girth, body length, round measurement, depth of chest, head length, head width, and width of cannon bone. Since one of us (FDC) was primarily concerned with physiology, many dwarf animals were brought to our laboratory for observation, experimentation, slaughter, or autopsy, and the measurements were taken there rather than in the field. Breeders were contacted in several ways. Many of those having difficulty approached us. The California Agricultural Extension Service proved most helpful in gaining entree to other breeders in the state. Some of the breed associations were of great assistance in providing contacts with breeders both within and outside the state. Without exception all herd owners contacted were interested and cooperated well. The breeders' desire for "no publicity" was respected at all times.

Observations

A dwarf may easily be mistaken at birth for a normal calf by veteran breeders or by cattlemen who observe one for the first time. In fact the tendency is for the uninitiated to mistake a new-born dwarf for an individual of great promise. Once the true form of the dwarf is visualized and comprehended, however, recognition at birth is easy. One of its outstanding features is that its body proportions approach those of a mature animal rather than a calf. A characteristic of dwarfs observed in Hereford, Angus, and Shorthorn breeds is that of thick

or heavy breathing as if there were an obstruction along the respiratory passage. The respiration often resembles labored breathing after violent exercise. This characteristic may not be perceptible at birth but usually becomes apparent by two months of age or soon thereafter. Although the expression of this characteristic varies considerably, it appears to be one of the symptoms of this specific type of dwarfism.

A second manifestation includes an extreme brachycephalic head and a mandible too long for the opposing maxilla. If the head length is obtained, this discrepancy becomes quite apparent. The tip of the

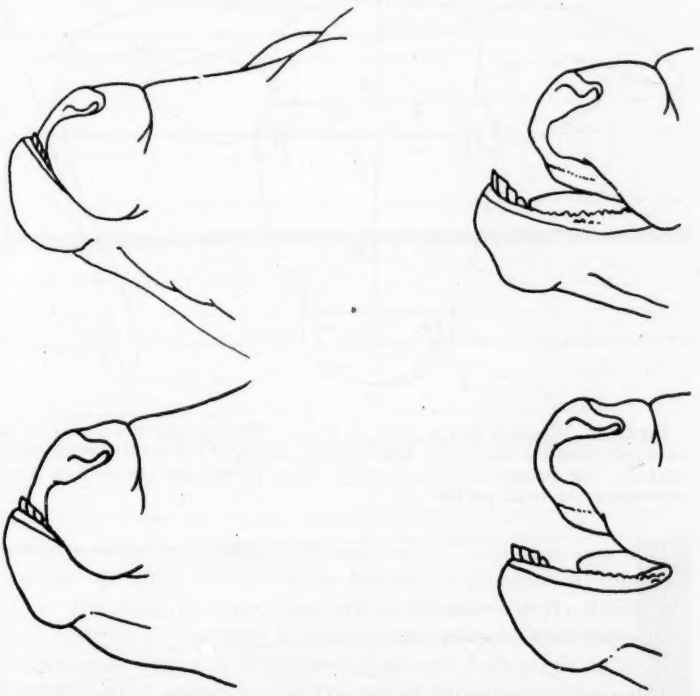

Figure 1. Top. A Hereford female 27 months of age. The diagram to the left shows the position of the teeth when the mouth is closed. The diagram at the right shows the mouth open, the incisors extend far in front of the dental pad.

Bottom. An Angus female 20 months of age. The diagram at the left shows the position of the teeth when the mouth is closed. The diagram at the right shows the mouth open, the teeth extend far in front of the dental pad.

nose represents the most forward point of the head in normal cattle, while in dwarfs the tip of the mandible is often the most forward point. Associated with this phenomenon is malocclusion of the incisors with the dental pad. More than 60 dwarfs have been observed, and in all except one or possibly two instances, the incisors were forward to the anterior limit of the dental pad from one-half to three and one-half centimeters, thus resulting in serious malocclusion (figure 1). Observations upon normal young calves indicate that a slight malocclusion

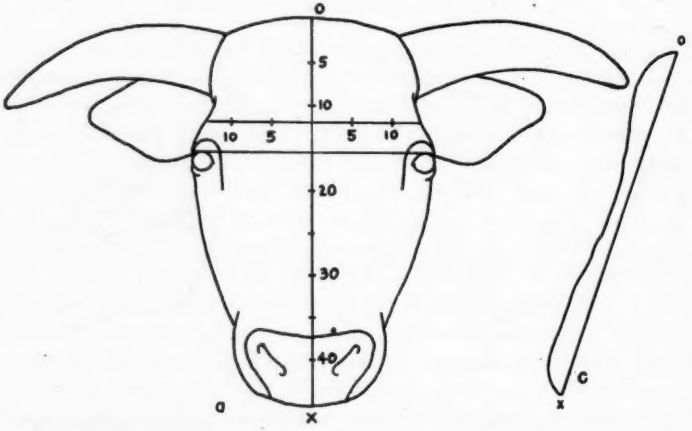

Figure 2. Diagram of the head of a cow. The median head contour is obtained along the line "o-x". The figure to the right is a rather typical head contour. The straight line "o-x" is the "base", while the curved line "o-x" represents the head profile.

of this type may be of rather common occurrence at early ages, but normality is evidently established at a relatively early age in most individuals. It is evidently a rare occurrence for normality to be established in this specific type of dwarf. A misshapen, protruding lower jaw or an ill-matched maxilla and mandible is a trait characteristic of the dwarf. Observation of the occlusion of molars is more difficult and has not been attempted in the routine check.

Perhaps the feature of the dwarf in greatest need of amplification concerns the forehead. Johnson *et al.* (1950) state, "Slightly bulging foreheads are common, but this alteration is not extreme and may not be present." During the first months of observation the authors of this paper held a view similar to the one quoted. But after Gregory

and Brown (unpublished data) developed a precision instrument to obtain head contours for analysis of head form, it became apparent that, in addition to a shortening of the long bones, a bulging forehead

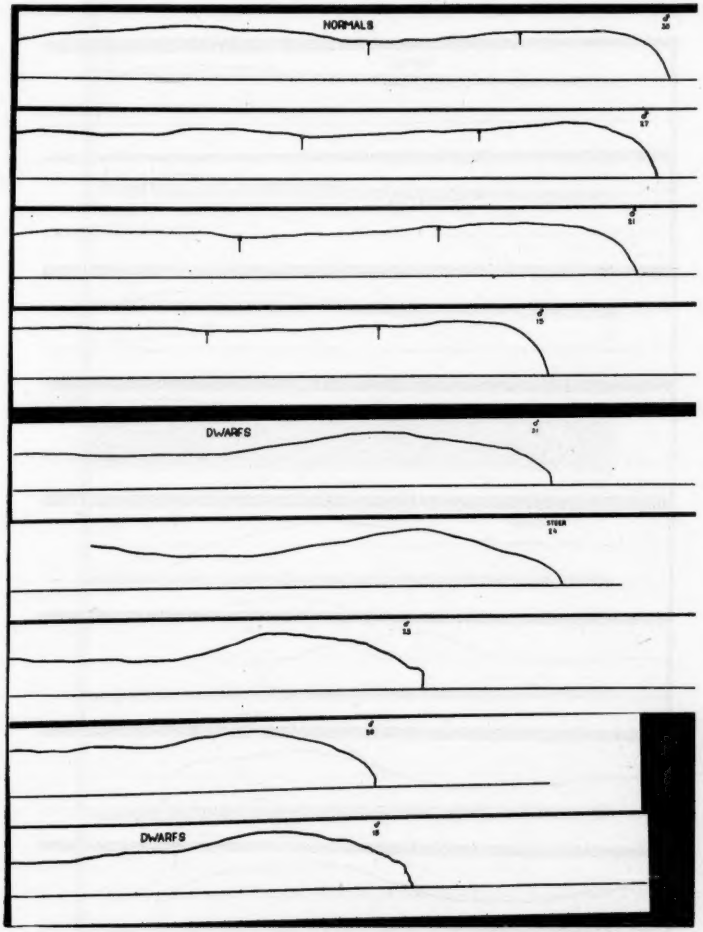

Figure 3. Head contours of normal and dwarf males from 15 to 33 months of age. The dwarf 24 months of age is a steer castrated at about 2 months of age. All the others are bulls. The normal animals have flat contours while the contours of dwarfs are well rounded in the region of the mid-forehead.

is perhaps the most constant and diagnostic characteristic of the dwarf of any age.

The median head contour or profile, as used in this analysis, represents the head form from the poll to the nose along the dorsal, median

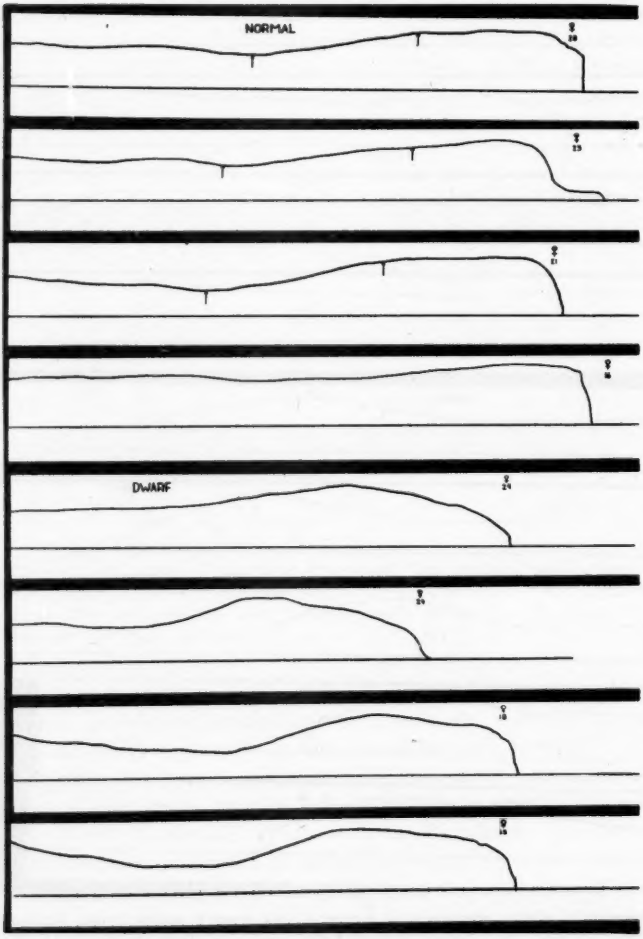

Figure 4. Head contours of normal and dwarf females from 13 to 29 months of age. All the dwarfs manifest the rounded mid-forehead prominence. This characteristic is lacking in the normal controls.

longitudinal axis (figure 2). It is obtained by means of the instrument developed by Gregory and Brown. Contours can be made with accuracy

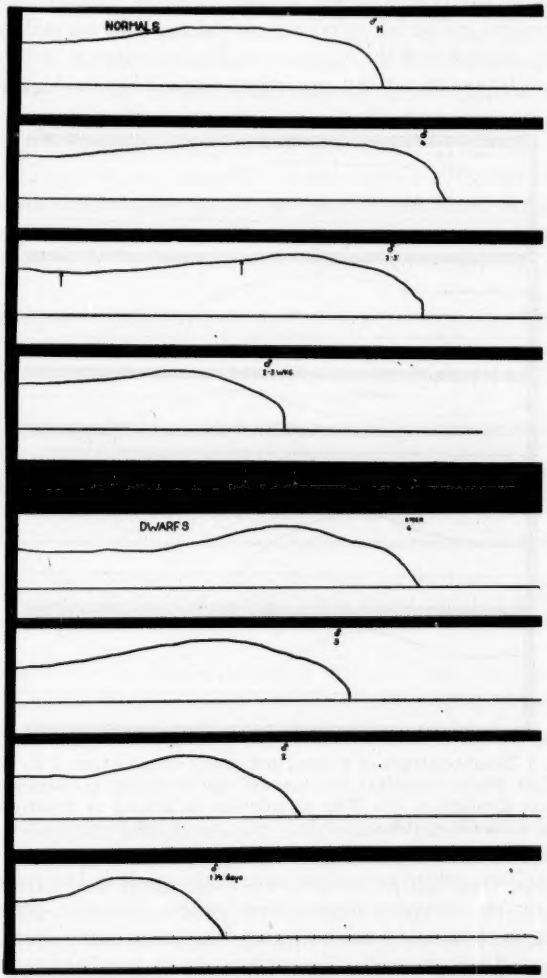

Figure 5. Head contours of normal and dwarf male calves from 2 days to 6 months of age. The dwarf 6 months of age is a steer. The mid-forehead prominence of normal calves is evident at this age but it is less pronounced than in the dwarf. This prominence disappears in normal calves but persists in the dwarfs.

and are repeatable. Those of dwarfs and normals of comparable ages in Herefords are shown in figures 3, 4, 5 and 6. More than 60 dwarfs of this particular type observed to date, including females, bulls, and steers, manifest a rounded prominence in the region of the mid-forehead consistently higher than the region of the frontal eminence. According to Sisson and Grossman (1938), the frontal eminence is the highest point

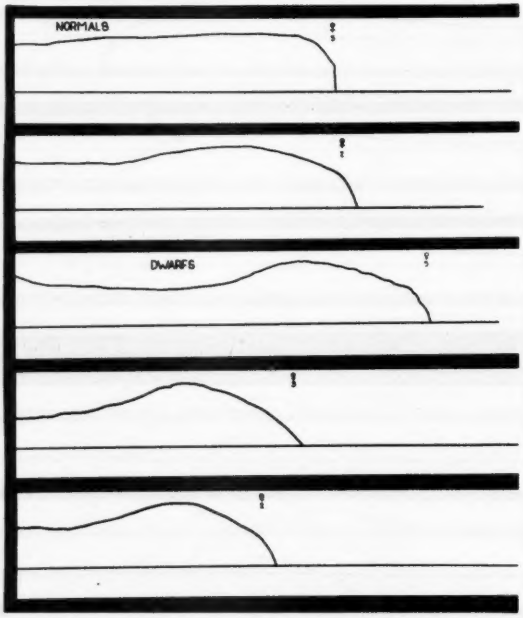

Figure 6. Head contours of normal and dwarf females from 2 to 5 months of age. The dwarfs manifest the rounded mid-forehead prominence which will persist throughout life. This prominence is lacking or greatly reduced in normal controls at this age.

of the skull in mature normal animals. Although it is less pronounced than in dwarfs, normal newborn calves possess a rounded prominence in the region of the mid-forehead higher than the frontal eminence. This juvenile condition gradually changes into the mature head form. Most of this metamorphosis takes place within the first year of age, the major changes occurring in the first few months after birth (figures 5 and 6). The dwarfs retain the exaggerated rounded prominence of the mid-forehead region into the mature state. Within limited age groups the high rounded profile of the mid-forehead region of the

dwarf is discontinuous with and does not intergrade into the type of profile peculiar to normal homozygotes. It is most valuable as a diagnostic character.

All the dwarfs considered thus far have been of Hereford breeding. Dwarfs of a similar appearance of Angus and Shorthorn breeds manifest a type of head contour which appears to be identical with the Hereford pygmy (figure 7). Thus dwarfs of these three beef breeds similar in appearance possess a common syndrome. Mating tests are now underway, which if successful should determine whether or not the same dwarf-conditioning gene is involved in the three breeds. Some dwarfish forms apparently unlike those considered in this report and by Johnson *et al.* (1950) have been encountered in calves of Hereford

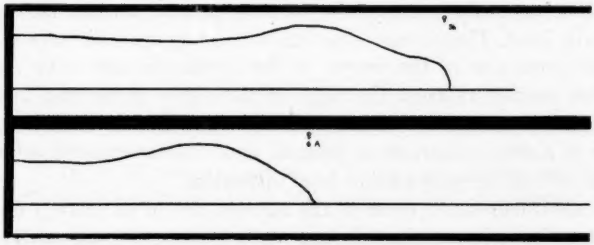

Figure 7. Head contours of Angus (bottom) and Shorthorn (top) dwarfs 6 months of age. Both of these individuals manifest the same type of head contour that is characteristic of Hereford dwarfs.

and Angus breeding. Thus it is possible that more than one genetic type of dwarfism may be involved within each breed of Hereford, Shorthorn, and Angus.

Discussion

The brachycephalic head, the bulging mid-forehead region, the marked malocclusion, and the other diagnostic features of the dwarfs have considerable biological import. All are distinctive characteristics of hereditary cretinism in man and animals (Fagge, 1871; Seligmann, 1904; Crew, 1924; Liddell, 1925; Landauer, 1929). All these morphological expressions are associated with a hypo-functioning thyroid, which in some instances may be conditioned by heredity. Experimental removal of the thyroid gland causes morphological changes similar to those found in the dwarf calves. Dye and Maughan (1929) report that puppies thyroidectomized at 5 to 6 weeks of age develop shorter, broader muzzles with a brachycephalic head, an excessively heavy

mandible, eyes wider apart, stunted bodies that are pot-bellied and hump-backed, and feet and legs relatively thicker and heavier in proportion to length. The changes in the skull are not expressions of retardation but of disproportionate growth. Membranous bones are little affected. Todd and Wharton (1934) observed that thyroid deficiency in sheep produced symptoms similar to those observed in thyroidectomized dogs. Dye and Kinder (1934) present additional evidence that the effect of the thyroid gland is a prepotent agent in determining skull shape. The studies of thyroidectomized calves by Spielman *et al.* (1945) show that removal of the thyroid early in life results in a cretin not greatly unlike hereditary cretins.

The brachycephalic head and the bulging forehead of the dwarf are assumed to be related and manifestations of the same phenomenon. The brachycephaly is caused for the most part by a wider rather than a shorter head. Thus it seems that the motivating agent or force causing lateral expansion in the region of the zygomatic arch may also be exerted dorsally to cause the bulge in the region of the mid-forehead. It is conceivable that the excessive fluid in the lateral ventricles of the brain of a dwarf observed by Johnson *et al.* (1950) may be related to and a part of the pathology of head distortion.

In the collaborative effort of the authors, one of us (FDC) directed his attention almost exclusively to a study of the endocrine relationship. In the Hereford, one series of experiments proves that the hypophyseal growth hormone of the dwarf is highly potent (Carroll, Gregory, and Rollins, unpublished); while another series of experiments indicates that the thyrotrophic hormone of the pituitary gland is grossly deficient (Carroll, Gregory, and Rollins, 1951). Thus in the dwarf of one breed we have positive proof that a thyroid deficiency is involved. This is not proof, however, that the same conditioning gene is involved in all three breeds.

It is likely that any gene appreciably impairing or reducing thyroid activity may produce some of the manifestations of thyroid deficiency. Thus several genes might produce similar phenotypic effects. It will require breeding tests to determine whether one dwarf-conditioning gene is common to all the breeds or whether more than one is involved. There is some expression of the dwarf gene in the heterozygous state. Heterozygous expression will be discussed in a later report.

Summary

A study of head contours of over 60 dwarfs and several hundred normal animals of the Hereford, Angus, and Shorthorn breeds reveals that the outstanding characteristic of the specific type of dwarfism

studied is a brachycephalic head with a marked mid-forehead prominence present at birth and persisting throughout life. This type of contour is discontinuous with and does not intergrade into the type of contour of normal homozygotes. Accompanying this anomaly is a misshapen mandible in which there is marked malocclusion of the incisors with the dental pad. Incisors may extend forward to the dental pad from one-half to three and one-half centimeters. These characteristics are also symptoms of thyroid deficiency. Moreover, the stunted growth, heavy breathing, and extreme pot-belly of the dwarfs are manifestations of thyroid deficiency characteristic of hereditary or experimentally induced cretins. These morphological features are in agreement with physiological studies completed in our laboratory being reported in another paper which prove conclusively that dwarfs of this type possess a gross deficiency of the thyrotrophic hormone.

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THE VALUE OF AMMONIATED CONDENSED DISTILLERS MOLASSES SOLUBLES AS A FEED FOR BEEF CATTLE[1]

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INDUSTRIAL by-products have long been used as feeds for livestock. Recently a new by-product has been developed by condensing the residue from yeast fermentation of cane molasses to commercial alcohol. This product, known as Condensed Distillers Molasses Solubles, has the following approximate chemical analysis: Crude protein—4 to 5%, NFE—28 to 30%, Water—39 to 40%, and Ash—15 to 17%. As it will combine with anhydrous ammonia, the nitrogen level can be increased to give a protein equivalent of approximately 13 percent.

No information concerning the value of this product as a feed for beef cattle appears in the literature. There has been, however, some work reported on similar products. Knodt *et al.* (1950) found ammoniated cane molasses could be used as a partial substitute for protein in the ration of dairy calves. The product gave good growth when used as 10% of their rations.

Culbertson and co-workers (1950) found that ammoniated cane molasses, when fed to beef cattle, was a protein and energy extender. When this product replaced one-half of the linseed meal, better results were obtained than with linseed meal as the sole protein supplement.

This experiment was designed to study ammoniated Condensed Distillers Molasses Solubles as a protein and energy extender when used in the ration of growing beef cattle.

Experimental Procedure

Two fifty-six day feeding trials were conducted. In the first trial 15 animals were distributed on the basis of sex, weight, and breeding into 3 lots of 5 animals each. One-day weights were taken at the start and at 14 day intervals thereafter. The animals were hand-fed the concentrate ration once daily. Grass hay, water, and minerals were given *ad libitum*. Alfalfa hay was given at one feeding once a week. Daily feed consumption records were kept.

[1] Published with the approval of the Director of the Louisiana Agricultural Experiment Station.

[2] The cooperation of Dr. H. R. Stiles and the Commercial Solvents Corporation is acknowledged and appreciated. The authors are also indebted to Professors C. B. Singletary and S. E. McCraine and to Mr. C. Alsbrooks for aid in conducting the experiment.

The composition of the rations is shown in table 1. The ammoniated Condensed Distillers Molasses Solubles used in this experiment came from Hawaiian molasses. Ration 1 has been used previously by the authors with excellent results. It is designated as the control ration. Rations 2 and 3 contain the ammoniated Condensed Distillers Molasses Solubles as shown in table 1. The ammoniated Condensed Distillers Molasses Solubles and molasses were mixed prior to the start of the experiment and stored in metal drums. The liquid portion of all rations was mixed with the dry concentrate feeds at the time of feeding.

TABLE 1. COMPOSITION OF RATIONS USED IN EXPERIMENTS 1 AND 2

Item	Lot 1	Lot 2	Lot 3
Corn	46.00	40.00	44.00
Cottonseed meal	23.00	20.00	16.00
Molasses	31.00	.....	.....
CDMS Mixture 1[1]	.....	40.00	.....
CDMS Mixture 2[2]	.....	.....	40.00

[1] 75% molasses—25% ammoniated Condensed Distillers Molasses Solubles.
[2] 50% molasses—50% ammoniated Condensed Distillers Molasses Solubles.
All lots were fed a mineral mixture and grass hay free choice. In addition alfalfa hay was given at one feeding one day each week.

The amount of concentrate feed was restricted, as it is believed this gives a more critical evaluation of the product. The intake of crude protein (Nitrogen x 6.25) and gross energy, as determined with a bomb calorimeter, from the concentrate feed were approximately equal in all lots. This was accomplished by increasing the amount of concentrate feed of the animals receiving rations 2 and 3.

The data were analyzed by the method of Analysis of Variance as described by Snedecor (1946).

Growth Rates

Growth rates and feed consumption data are presented in table 2. In the first trial the highest average daily gains were made by lot 1 (control) followed by lots 2 and 3, respectively. These differences were not significant at the 5 percent level. Examination of the 14-day gains reveals the greatest difference between lots at the end of the first period. This difference became less for each successive period. Inspection of the hay consumption during the last three periods reveals there was no great difference between the two lots. As the consumption of concentrate was constant throughout the experiment, the animals receiving ammoniated

Condensed Distillers Molasses Solubles were possibly making more efficient use of their feed during the last three periods than during the first period. This indicates time is required to change the rumen microflora for utilization of rations containing ammoniated Condensed Distillers Molasses Solubles.

TABLE 2. GROWTH RATE AND FEED CONSUMPTION

	Experiment I			Experiment II		
Ration and Lot No.	1	2	3	1	2	3
Animals per lot	5	5	5	4	4	4
Days on feed	56	56	56	56	56	56
Average final weight	504	495	492	501	506	492
Average initial weight	427	427	430	406	406	411
Average daily gain	1.39	1.21	1.11	1.69	1.77	1.44
Average daily ration						
Corn	3.15	2.93	3.31	3.12	2.90	3.28
CS meal	1.57	1.47	1.20	1.56	1.45	1.19
Molasses	2.12	2.20	1.50	2.10	2.18	1.49
CDMS	....	0.73	1.50	....	0.73	1.49
Total Concentrates	6.84	7.33	7.51	6.78	7.26	7.45
Grass hay	10.35	9.81	9.70	9.51	8.78	9.81
Alfalfa hay	1.41	1.40	1.40	0.76	0.81	0.79
Total Hay	11.76	11.21	11.10	10.27	9.59	10.60
Total feed	18.60	18.54	18.61	17.05	16.85	18.05
Feed per 100 lbs. gain						
Corn	227	241	300	185	164	227
CS meal	114	121	109	92	82	83
Molasses	153	181	136	125	123	103
CDMS	...	60	136	...	41	103
Total Concentrates	494	603	682	402	409	516
Grass hay	747	808	878	564	495	681
Alfalfa hay	102	115	127	45	46	55
Total Hay	849	923	1005	609	541	736
Total feed per 100# gain	1343	1526	1687	1011	950	1252

In the second trial, the greatest gains were made by the animals in lot 2, followed by lots 1 and 3 in the order named. These differences were not significant. Inspection of gains by periods reveals the same trend as in the first trial. The heifers used in this trial made greater gains than the animals used in the first trial. The heifers used in the second trial had gone through the winter on a low plane of nutrition and

had lost weight, while the animals used in the first trial were in good condition when started on the experiment.

Feed Consumption and Efficiency

In the first trial, the daily intake of concentrate feed was 6.84, 7.33 and 7.51 pounds per animal for lots 1, 2 and 3, respectively. The differences were necessary in order to equate the caloric and crude protein intake of the three groups. It is interesting to note the total

TABLE 3. GROSS ENERGY CONSUMPTION AND EFFICIENCY

	Experiment I			Experiment II		
Ration and Lot No.	1	2	3	1	2	3
Daily energy consumption						
Corn	6.34	5.89	6.66	6.28	5.83	6.60
CS meal	3.10	2.90	2.37	3.07	2.86	2.35
Molasses	2.65	....	....	2.63	....	....
Molasses-CDMS mix	....	3.46	3.32	....	3.42	3.31
Total Concentrates	12.09	12.25	12.35	11.98	12.11	12.25
Grass hay	17.85	16.92	16.73	16.40	15.14	16.92
Alfalfa hay	2.48	2.47	2.47	1.34	1.43	1.39
Total Hay	20.33	19.38	19.20	17.74	16.57	18.31
Total therms	32.43	31.64	31.54	29.72	28.68	30.56
Gross energy (therms) per 100 lbs. gain						
Concentrate	872.78	1008.93	1120.54	709.47	683.56	849.01
Hay	1466.53	1596.37	1738.23	1051.42	934.27	1270.02
Total	2339.31	2605.30	2858.78	1760.89	1617.83	2119.03

intake of feed was approximately the same for all groups. The animals receiving the control ration required less feed per unit gain, followed by those receiving rations 2 and 3, respectively.

Consumption of concentrate feed was in the same order as in the second trial. The animals in lot 3 consumed more hay and total feed than did the other two lots, but made less efficient use of their feed. They required 1,252 pounds of feed per hundred pounds gain. Lots 1 and 2 required 1,011 and 950 pounds, respectively. All animals in the second trial utilized their feed more efficiently than did the animals in the previous trial. It is possible the poorer starting condition of the animals and the milder temperature during the latter trial contributed to this situation.

Energy Consumption and Efficiency

Gross energy consumption for both trials appears in table 3. In the first trial the daily consumption of gross energy was 32.43, 31.64, and 31.54 therms for lots 1, 2, and 3, respectively. Animals in lot 1 were most efficient in converting gross energy to gain, followed by those in lots 2 and 3.

In the second trial greatest consumption of gross energy was by lot 3, followed by lots 1 and 2. Lot 3 made the poorest use of gross energy, requiring 2119.03 therms per 100 pounds gain; lots 1 and 2 required 1760.89 and 1617.83 therms per 100 pounds gain. It is interesting to note that in the first trial the efficiency of the rations was in the same order as the consumption of energy, i.e., the higher the daily consumption the greater the efficiency. In the second trial the reverse was true.

Summary

In two trials no significant differences in gain were noted when ammoniated Condensed Distillers Molasses Solubles replaced 25 percent and 50 percent of the molasses in a normal ration for growing cattle. However, in both trials the lots receiving the ration with 50 percent ammoniated Condensed Distillers Molasses Solubles made the lowest gains.

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METHODS OF FEEDING CANE MOLASSES AND UREA TO BEEF CATTLE[1]

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Louisiana Agricultural Experiment Station[3]

In the Gulf Coastal area there is a fairly constant supply of blackstrap or cane molasses. At times the price is so low that it is the cheapest available source of carbohydrate feedstuff for livestock. This condition is responsible for much research work on the product. Gulley and Carson (1890), Lindsey *et al.* (1907), Burns (1908), Bray *et al.* (1945), and others have shown that cane molasses is a valuable feed for cattle.

Snell (1935) found that the addition of cane molasses to the ration of beef cattle did not alter the digestibility of any components. If, however, silage was included in the same ration, there was a decrease in the digestibility of fiber and protein. Burroughs *et al.* (1950) in studying the abilities of certain feeds to stimulate rumen microorganisms in the digestion of cellulose in an artificial rumen, found cane molasses to exert a favorable effect. Lindsey *et al.* (1907) found that molasses reduced the digestibility of crude fiber in cattle rations.

Willett and co-workers (1946) found that when cane molasses constituted 25 percent of the concentrates in the ration of the dairy cow urea was utilized very efficiently. Bowstead and Fredeen (1948), however, found that molasses was essential for the utilization of urea included in the rations of their dairy cows.

Bray *et al.* (1945) described six ways of utilizing cane molasses in beef cattle rations. This experiment was designed to compare several methods of feeding cane molasses in a fattening ration for beef cattle.

Experimental Procedure

Two separate feeding trials were conducted. The first trial was designed to compare four methods of feeding molasses. The second trial was designed to duplicate two rations of the first trial and to test the value of adding urea (two-sixty-two) to rations containing molasses.

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[2] Deceased March 23, 1950.
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Experiment I

Eight steers were allotted into each of five lots on the basis of weight, age, and breed. The steers were of various Brahman-Angus and Africander-Angus crosses and were approximately 10 months old when placed on the experiment. They were placed in pens of approximately equal size and started on feed November 24, 1949, and continued for 140 days. The composition of each ration is shown in table 1. They were group-fed the concentrate twice daily. The animals were gradually brought to full feed and maintained there for the remainder of the test. As care was taken to maintain some feed in the troughs at all times the

TABLE 1. COMPOSITION OF RATIONS

Experiment I

Ration	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
	%	%	%	%	%
Corn	79	46	46	46	30.4
Cottonseed Meal	21	23	23	23	30.4
Cane Molasses	..	..	..	31	39.2
Molasses-Bagasse	..	31	..	..	....
Molasses-CS Hulls	..	..	31	..	....
Grass Hay	free choice	free choice	free choice	free choice	free choice
Mineral Mixture	free choice	free choice	free choice	free choice	free choice

Alfalfa hay fed once a week to all lots.

animals were essentially being fed *ad libitum*. The molasses-bagasse[4] and the molasses-cottonseed hulls mixtures were dehydrated feeds. These were mixed with the other dry ingredients to form rations 2 and 3. In rations 4 and 5 the molasses used was in the liquid state. To prepare ration 4, corn and cottonseed meal were premixed and the molasses added at the time of feeding. The animals receiving ration 5 had free access to molasses in a metal-lined trough and to a mixture of equal parts of corn and cottonseed meal. The proportion of molasses in this ration is based upon the amounts of these ingredients actually consumed.

One-day weights were taken at the beginning of the experiment and at 28-day intervals throughout the test. The animals were deprived of water for a period of 12 hours prior to each weighing.

[4] The molasses-bagasse mixture was a commercial product sold under the trade name of Camola. Essentially, Camola is molasses from which the water has been removed by drying and replaced by a slightly larger quantity of sugar cane pulp.

Experiment II

This trial was designed to duplicate rations 1 and 4 of the first trial and to extend the study by feeding two rations containing different amounts of urea in molasses. The composition of the rations is shown in table 2.

The urea used in rations 3 and 4 was readily soluble in molasses. Subsequent nitrogen determinations indicated the mixing was complete and that the urea remained in solution. Gross energy determinations were made with a bomb calorimeter.

Thirty-two steers of approximately the same breeding as those used in the first trial were equally distributed among four lots. The methods

TABLE 2. COMPOSITION OF RATIONS

Experiment II

Ration	Lot 1	Lot 2	Lot 3	Lot 4
	%	%	%	%
Corn	79	46	55	60
Cottonseed Meal	21	23	5	..
Molasses	..	31	..	..
Urea in Molasses	..	..	40[1]	40[2]
Prairie Hay	free choice	free choice	free choice	free choice
Mineral Mixture	free choice	free choice	free choice	free choice

[1] Urea dissolved in molasses—8% urea and 92% molasses.
[2] Urea dissolved in molasses—10% urea and 90% molasses.
Alfalfa hay fed once a week to all lots.

of feeding, weighing and handling the animals were the same as in the previous trial. This trial was terminated at the end of 112 days. The data were analyzed by the method of analysis of variance as described by Snedecor (1946).

Results and Discussion

Growth Rate and Carcass Grades

The data summarizing the effect of treatment on growth rates and carcass grades appear in tables 3, 4, and 5.

In the first trial (table 3) lots 2 and 3 made lower daily gains than the others, but none of the differences were significant at the five percent level. The carcass grades followed the trend of daily gains in all lots. The animals receiving the molasses-bagasse and the molasses-cottonseed hulls mixtures made smaller gains and carried less finish than the

animals receiving rations 1, 4, and 5. It is interesting to note that of the two rations containing liquid molasses, the group receiving the higher amount (lot 5) carried somewhat less finish.

The particular period of time covered by this trial was very undesirable for full feeding animals. There were several long periods of

TABLE 3. EFFECT OF METHOD OF FEEDING CANE MOLASSES ON GROWTH AND FATTENING OF STEERS

Experiment I—1949–50

Number of Days—140

Item	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5
Steers per group	8	8	8	8	8
Average final weight	701	651	649	709	701
Average initial weight	484	482	480	481	481
Average gain	217	169	169	228	220
Average daily gain	1.55	1.20	1.20	1.63	1.58
Feed per 100# gain					
Corn	587	453	466	341	219
Cottonseed meal	156	226	233	172	219
Molasses	...	...	...	231	282
Molasses-bagasse	...	305	...	...	...
Molasses-CS hulls	...	...	314	...	...
Total Concentrates	743	984	1013	744	720
Grass Hay	326	365	366	301	362
Alfalfa Hay	37	47	47	35	37
Total Hay	363	412	413	336	399
Total feed per 100# gain	1106	1396	1426	1080	1119
Average daily feed					
Concentrates	11.5	11.9	12.3	12.2	11.3
Hay	5.6	5.0	5.0	5.5	6.3
Total	17.1	16.9	17.3	17.7	17.6
Average Carcass Grade	L-Good	H-Med.	H-Med.	Good	L-Good

extremely hot weather followed by periods of variable weather. The weather and the age of the animals may account in part for the low gains in all lots.

The high fiber content of the molasses-bagasse and molasses-cottonseed hulls mixtures probably accounts for the smaller gains obtained with these rations. The similarity in daily gains between these two lots was not due entirely to the fiber content. This becomes apparent from the following chemical analysis of the molasses-bagasse and molasses-

cottonseed hulls mixtures, respectively: crude protein, 3.0 and 3.6%; ether extract, 0.1 and 0.6%; crude fiber, 12.1 and 24.0%; nitrogen free extract, 70.4 and 58.0%. These analyses indicate that in this test

TABLE 4. EFFECT OF METHOD OF FEEDING CANE MOLASSES ON GROWTH AND FATTENING OF STEERS

Experiment II—1950–51

Number of Days—112

Lot and Ration Number	1	2	3	4
Composition of Concentrate Ration	Corn 79% CS Meal 21%	Corn 46% CS Meal 23% Molasses 31%	Corn 55% CS Meal 5% Urea-Mol. 40%	Corn 60% Urea-Mol. 40%
Steers per group	8	8	8	8
Average final weight	651	640	620	625
Average initial weight	460	459	462	467
Average gain	191	181	158	157
Average daily gain	1.70	1.61	1.40	1.40
Feed per 100# gain				
Corn	602	386	491	568
Cottonseed meal	160	193	45	...
Molasses	...	260	329	341
Urea	...	...	29	38
Total Concentrates	762	839	894	947
Grass Hay	231	295	350	333
Alfalfa Hay	58	61	73	71
Total Hay	289	356	423	404
Total feed per 100# gain	1051	1195	1317	1351
Average daily feed				
Corn	10.27	6.21	6.89	7.98
Cottonseed meal	2.73	3.11	0.63	....
Molasses	....	4.19	4.61	4.79
Urea	....	....	0.40	0.53
Grass Hay	3.94	4.75	4.91	4.68
Alfalfa Hay	0.99	0.97	1.02	1.00
Total	17.93	19.23	18.46	18.98
Average carcass grades	Good	Good	L-Good	Good

the crude fiber from cottonseed hulls was better utilized than was the fiber from bagasse. This may be due in part to the higher lignin content of the bagasse.

The results of the second feeding trial are shown in table 4. Rations

1 and 2 produced similar daily gains. The close agreement of these results with those obtained in the first trial indicates the rations have approximately the same value.

The two rations (3 and 4) containing urea dissolved in molasses did not give as high daily gains as did either ration 1 or 2. This difference, however, was not significant at the five percent level. These rations

TABLE 5. DAILY INTAKE OF GROSS ENERGY AND EFFICIENCY

Experiment II

	Lot 1	Lot 2	Lot 3	Lot 4
Therms of energy from:				
Corn	20.721	12.529	13.901	16.101
Cottonseed meal	5.393	6.144	1.245	.....
Cane molasses	.....	5.246	5.771	5.997
Urea	.....	.....	0.454	0.601
Grass hay	6.795	8.192	8.468	8.071
Alfalfa hay	1.744	1.709	1.797	1.761
Total intake	34.653	33.819	31.635	32.531
Percent energy from:				
Corn	59.8	37.0	43.9	49.5
Cottonseed meal	15.6	18.2	3.9	....
Cane molasses	....	15.5	18.2	18.4
Urea	....	....	1.4	1.8
Total Concentrates	75.4	70.7	67.4	69.7
Grass hay	19.6	24.2	26.9	24.8
Alfalfa hay	5.0	5.1	5.7	5.5
Total hay	24.6	29.3	32.6	30.3
Therms per 100 lbs. gain from:				
Concentrates	1531.472	1485.155	1523.610	1615.097
Hay	501.587	616.004	732.873	698.305
Total	2033.059	2101.159	2256.483	2313.402

contained rather high levels of urea, since it was thought that the high level of sugars in molasses would aid in the utilization of the urea nitrogen. It is possible that the urea levels were too high. Chemical analysis (nitrogen x 6.25) shows that in ration 3 urea furnished 51.3% of the protein in the concentrate and 43.2% of the protein in the total ration. Comparable figures for ration 4 are 62.7% and 53.2%. If it is assumed that the levels of urea were too high, it becomes difficult to explain why ration 4 gave as good or better results than did ration 3. It seems more likely that the lower energy concentration due to the molasses in these rations was responsible (table 5). This suggestion is

supported when rations 3 and 4 are compared. Late in the trial one animal in lot 4 was found to be a bull and castration was necessary. He became infected and his total gain was only 35 pounds; therefore, he should probably not be included in this group. If he were omitted, the average daily gain would become 1.50 pounds.

Feed Consumption

Feed consumption data are summarized in tables 3, 4, and 5. In the first experiment, it is interesting to note that rations 4 and 5 compared very favorably with ration 1 in the conversion of feed to gain. As molasses generally contains less energy than corn it is difficult to explain this. Energy values were not determined on these rations. The slower gaining animals receiving rations 2 and 3 made less efficient use of their feed than those animals receiving the other three rations. This may be due to the higher fiber content of these two rations.

The results of the second trial appear in tables 4 and 5. In this trial rations were compared on the basis of energy consumption. Lot 1 required 2,033 therms of energy per 100-pound gain, while lots 2, 3, and 4 required 2,101, 2,256, and 2,313 therms respectively. The trend of the effect of greater energy concentration on food utilization is followed in rations 1 and 2. This does not explain the difference between lots 3 and 4.

Summary

Two feeding trials involving 9,184 steer days were conducted to study methods of feeding molasses to growing and fattening beef cattle. In the first trial 40 young steers were divided into 5 equal groups. Four of these lots received molasses and one lot received a control ration containing no molasses. Two of the molasses-fed lots received liquid molasses and the other two received dehydrated molasses feeds. One of the dehydrated mixtures contained cottonseed hulls as an absorbent and the other bagasse. All animals receiving liquid molasses made satisfactory gains. The gains of those receiving the dehydrated molasses were not satisfactory.

The control and one molasses ration (ration 4) of the first trial were also included in the second trial. Similar results were obtained in either experiment, indicating the same value for these rations. The study was extended by adding urea to the rations of two other lots. Urea was dissolved in the molasses of either ration. In one ration urea supplied 51.3 percent of the protein in the concentrate and 43.2 percent

of the protein in the total ration. Comparable figures for the other ration were 62.7 and 53.2.

Similar gains were made by the lots receiving either level of urea. These gains were lower than those made by lots receiving the control ration. The difference, however, was not significant at the five percent level. More feed or energy was required to produce a unit of gain by the animals receiving urea. The urea did not alter the palatability of the molasses, i.e., feed refusals were no more frequent with the urea-fed animals. No harmful physiological effects of urea were apparent in any of the animals receiving it in their ration.

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NET ENERGY VS. T.D.N. IN EVALUATING THE EFFICACY OF AN ALL-ALFALFA HAY RATION FOR MILK PRODUCTION[1]

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IT has been reported by Huffman (1938) and Huffman and Duncan (1944, 1949, 1950) that when cows were fed on specific alfalfa hays alone for several weeks or more they would be depleted of a certain milk stimulating factor or factors which were present in other hays or concentrates. In changing from alfalfa hay to alfalfa hay plus a concentrate on an equal total digestible nutrient (T.D.N.) basis, significant increases in milk production were obtained. They concluded that many hays were deficient in a factor or factors which were contributed by the concentrate and were responsible for the increased production. Davis and Kemmerer (1948) using a similar procedure reported such factors existed in dried grapefruit peel. Smith *et al.* (1945) supported Huffman's conclusions but felt that net energy gave a more correct feeding value for hays. Saarinen *et al.* conducted similar experiments in which hay was replaced by concentrates on a net energy basis and found no increases in milk production. From their calculations they concluded that the increases reported by other workers could be explained on the basis of an increase in net energy in the ration when changing from hay to hay plus a concentrate on the T.D.N. basis.

It has been argued by many workers in the United States that the net energy method of calculating the feeding values of various rations can not be determined accurately and, therefore, should not be used. Armsby and Forbes were the original sponsors of net energy in the United States and their feeding table values were based on calorimetric measurements. Kuhn, Kellner, Hansson and others of Europe have been largely responsible for the development of net energy feeding standards and for their wide popularity in Europe.

The difficulties in determining true net energy values have been discussed by Ritzman and Benedict (1938), Kriss (1943), Kleiber (1935),

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Mitchell (1935), Marston (1948), Armsby (1922, 1916) and others who have worked directly with these problems. For example, as pointed out by Ritzman and Benedict (1938) the lability of basal metabolism might vary as much as 80 percent for the same cow on the same feed over a period of several months. The followers of T.D.N. with less experience in the problems involved have been quick to point out the many inadequacies apparent in the net energy system. Kleiber *et al.* (1945) in a critical review of net energy systems of feed evaluations concluded that the Scandinavian group trial method was best.

Workers such as Morrison (1937), Fraps (1925) and Kleiber *et al.* (1945) have realized the shortcomings of the T.D.N. system and have attempted to develop "production or replacement equivalent feed values" based on the actual production values of the various feeds. These systems were never developed extensively nor accepted by research workers in this country. As a result the United States workers have used the T.D.N. system almost exclusively.

The Scandinavian group trial method as elaborated by Nils Hansson of Sweden in 1923 had its beginning in the Thaer hay value system developed in Germany in 1810. This system used barley as a reference substance. The Scandinavian method of calculating net energy as expressed by Larson (1945) is similar to Kellner's (1913) method. Larson used Kellner's factors plus certain correction factors referred to as "value numbers" based upon a large number of Scandinavian group trials. These two systems of evaluating rations are used by European workers with the same degree of certainty as the T.D.N. system is used in this country. There is a general feeling in Europe that American workers are lagging behind in feed evaluation practices and procedures.

Many workers have studied the effect of improper balance of rations and their influence upon digestibility and milk production. Ritzman and Benedict (1938) have pointed out that the ratio of digestible protein to energy affects the digestibility of the protein as the ratio widens. Nordfeldt *et al.* (1950) studied the relationship of digestibility to the crude fiber content of a ration. This work confirmed that of previous workers in concluding that as crude fiber content increases, the digestibility of certain nutrients, including crude fiber, decreases. They suggested that the increases obtained by Huffman may have resulted from a decrease in crude fiber content upon changing from hay to hay plus a concentrate ration. Morrison *et al.* (1933) and Forbes *et al.* (1931) have reported increased digestibility of hay plus corn over hay alone. Watson *et al.* (1941, 1942, 1947, 1935, 1936) have reported no associative effect with hay and hay plus grain. Graves *et al.* (1938) and

Moseley *et al.* (1929) have reported that cows utilized with equal efficiency hay or hay plus concentrate rations although other workers have been unable to confirm these reports. Smith *et al.* (1945) brought out the more commonly accepted version and concluded that the T.D.N. system highly overrated the feeding value of alfalfa hay except for the very best hays.

While it is granted that the T.D.N. system of evaluating feedstuffs does not differ too greatly from the net energy system when applied to many concentrates, it is not considered valid to use the T.D.N. system in making direct comparisons between a roughage and a concentrate.

Experimental

This experiment was inaugurated in October 1949 as a follow-up and continuation of the work of Saarinen *et al.* Seven cows consisting of five Holsteins, one Ayrshire and one Jersey were placed on an all-alfalfa hay ration shortly after parturition. This ration was continued until milk production and body weight had leveled off. The time lapse for this all-hay period varied from 86 to 150 days. It was felt that the length of time involved should have depleted the body reserves of each cow of any factor(s) needed for milk production in which the hay was deficient.

When each cow was placed on an all-alfalfa hay ration, both milk production and body weight dropped off sharply and reached a plateau. At this point the net energy in the ration was assumed to be sufficient for body maintenance and milk production.

Four lots of hay were used and digestion trials were run on these hays and on some of the concentrates. The feeding schedule is shown in table 1 and the analyses of the feeds used are shown in table 2.

In the beginning of the experiment the cows were fed all the hay they would consume. The net energy value of the hay was calculated and a part of the hay was replaced by a concentrate such as ground corn; a cellulose mix consisting of Ruffex (a purified rice straw cellulose), cane sugar and cornstarch in the ratio 8:1:1; a carbohydrate mix of cane sugar and cornstarch 1:1; corn distillers dried solubles; and soybean oil meal.

In most instances each cow was fed a ration for 12 to 15 days at the end of which time a 3 day digestion trial was run. Feed changeovers were 0 to 5 days in length. The hays and concentrates which were used are shown in table 2. The ration of each cow was supplemented with 115 grams of bonemeal and 45 grams of salt per day. The feed change-

overs were made on a net energy basis. In some instances increased energy was given while in others the changes were made isocalorically. Net energy calculations were based upon feed analyses and digestion

TABLE 1. FEED SCHEDULE

Figure	Cow	Experimental period	Days on Experiment	Type of hay	Hay fed daily	Type of concentrate	Concentrate fed daily
					lbs.		lbs.
1	Esmaryalda	1	70	No. 1 alfalfa, barn cured	38–40	none	
		2	16		40	none	
		3	14		28	Cell. mix.	8.4
		4	17		28	Dist. sol.	5.4
		5	16		39.3	none	
		6	14		39.7	Sugar-starch	6.0
2	Goldie	1	117	No. 2 alfalfa, field cured leafy	28–36	none	
		2	9		31	none	
		3	12		20	Sugar-starch	6.0
		4	12		18	Corn, crushed	6.0
		5	15		34	none	
3	Glory	1	128	"	26–32	none	
		2	12		31	none	
		3	12		19	Sugar-starch	6.0
		4	13		19	Dist. sol.	5.0
		5	3		32	none	
4	Ramona	1	107	"	29–34	none	
		2	14		33	none	
		3	13		20	Corn, crushed	6.0
		4	10		33.4	none	
		5	15		20.0	Corn, crushed	6.0
		6	10		32.6	none	
5	Abett	1	115	No. 1 alfalfa, barn cured	20–33	none	
		2	14		23	none	
		3	16		15	Cell. mix	5.0
		4	15		14	Corn, crushed	5.0
		5	17		23	none	
6	Faith	1	77	No. 1 alfalfa, field cured (rained on)	28–37	none	
		2	9		37.4	none	
		3	13		28	Cell. mix	6.4
		4	21		28	Corn, crushed	5.7
		5	8		35.8	none	
		6	23		20	Dist. sol.	5.0
		7	26		37.1	none	
7	Carrie	1	122	No. 2 alfalfa, field cured leafy	18–27	none	
		2	28	No. 2 alfalfa, field cured leafy, 2nd lot	26–28	none	
		3	15		16	Corn, crushed	5.0
		4	16		16	Soybean oil meal	5.0
		5	16		28	none	

trial data in accordance with the Scandinavian method (Larson 1945) of calculating net energy values. These figures and the calculated T.D.N. values are given in table 3. The method of calculating the value for hay is given below.

The nutrient content of the hay on a wet basis is multiplied by the digestion coefficient. Each digestible nutrient value is then multiplied by a specific factor for conversion to the starch value. For example, digestible protein is multiplied by 0.94, digestible crude fat by 1.91 and digestible crude fiber and nitrogen free extract by 1.0. The four values so obtained are added together and from their sum is subtracted

TABLE 2. FEED ANALYSES

Feed	Dry matter	Ash	Crude protein	Fat	Crude fiber	N.F.E.
	%	%	%	%	%	%
No. 1 alfalfa, barn cured hay	89.50	7.41	17.49	1.56	26.63	36.43
No. 1 alfalfa, field cured hay (Rained on)	86.70	6.41	15.79	0.82	32.55	31.20
No. 2 alfalfa, field cured hay leafy	86.30	5.95	14.44	1.10	28.87	35.93
No. 2 alfalfa, field cured hay leafy, 2nd lot	87.55	5.86	15.77	0.93	33.77	34.00
No. 1 dent corn, ground	86.80	6.12	8.50	2.70	1.88	67.60
Corn distillers dried solubles	94.85	6.96	34.13	11.89	2.76	39.11
Cellulose ("Ruffex")	93.38	0.72	1.08	0.54	67.75	23.30
Corn Starch	93.00	0.28	0.83	0.27	0.06	92.50
Cane Sugar	99.80					99.80
Soybean oil meal	91:10	5.51	40.40	4.83	5.24	26.92

a correction value for the crude fiber since this substance is responsible for the extra heat loss in work of digestion. This correction value is equal to the percent total crude fiber times 0.58 and when subtracted gives the corrected starch value. The corrected starch value multiplied by 1.071 gives the net energy value of the feed in therms per 100 pounds of feed. These values are expressed in table 3 in Calories per pound of feed. In the case of concentrates, different conversion factors are used and no deduction is made for the fiber content. The starch value thus obtained is multiplied by a "value number", which corrects the theoretical value to a slightly lower one as determined from a large number of Scandinavian group feeding trials.

TABLE 3. CALCULATED FEED VALUES OF HAYS AND CONCENTRATES

Type of hay or concentrate	Net energy value	T.D.N. value
	Cal./lb.	lb./100 lb.
No. 1 alfalfa, barn cured hay	417	53.3
No. 1 alfalfa, field cured hay (Rained on)	289	46.0
No. 2 alfalfa, field cured hay leafy	361	49.8
No. 2 alfalfa, field cured hay leafy, 2nd lot	322	49.7
No. 1 dent corn, ground	757	82.0
Corn distillers dried solubles	759	81.6
Cellulose ("Ruffex")	239	26.7
Sugar-starch 1:1	1010	98.6
Cellulose mixture	393	41.1
Soybean oil meal	728	71.5

Milk records were kept daily and samples were taken for butterfat tests once a week during the earlier part of the experiment and daily during the hay plus concentrate feeding periods. Milk production data were converted to 4 percent fat corrected milk (F.C.M.).

Results

The actual milk production along with the expected milk yield expressed in terms of T.D.N. and net energy are shown graphically in figures 1 through 7. Expected milk production on the T.D.N. basis was calculated by first determining the T.D.N. value of the ration consumed. From this value was subtracted the maintenance requirements of the cow. The maintenance requirements were based upon body weight

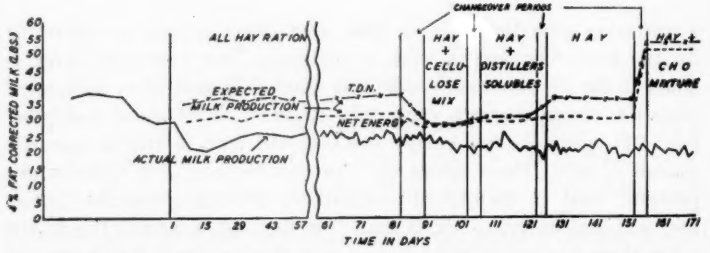

Figure 1. Actual milk production compared with expected milk production on a T.D.N. and net energy basis. CHO mixture consisted of cane sugar and corn starch in the ratio of 1:1.

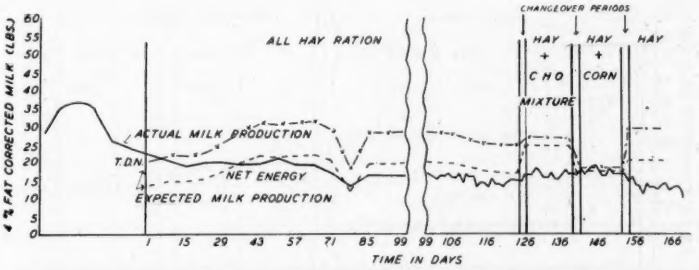

Figure 2. Actual milk production compared with expected milk production on a T.D.N. and net energy basis. CHO mixture consisted of cane sugar and corn starch in the ratio of 1:1.

data and the lower maintenance values given by Morrison (1948) were used because the cows were relatively thin after having been on the all-hay ration for several months. The remainder was divided by 0.315 to convert the T.D.N. into the expected pounds of 4 percent F.C.M.

In the calculation of the pounds of 4 percent F.C.M. expected on the net energy basis, the total net energy of the ration was calculated as mentioned previously. Maintenance requirements were again subtracted. The values used were the lower limits given by Morrison (1948). The remainder was divided by 0.295 to obtain the expected milk production in pounds of 4 percent F.C.M.

The abscissa of each graph represents the number of days that each cow had been on experiment. The ordinate denotes the pounds of 4 percent F.C.M. received or expected. Milk production lines in the early part of each experiment were calculated on a weekly basis.

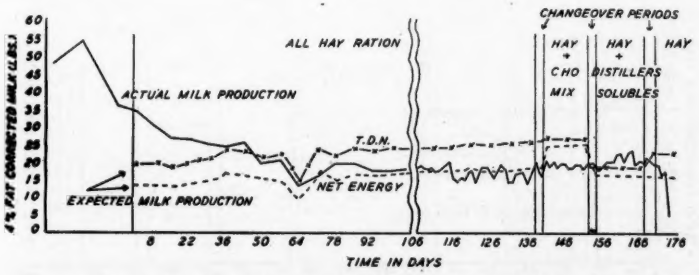

Figure 3. Actual milk production compared with expected milk production on a T.D.N. and net energy basis. CHO mixture consisted of cane sugar and corn starch in the ratio of 1:1.

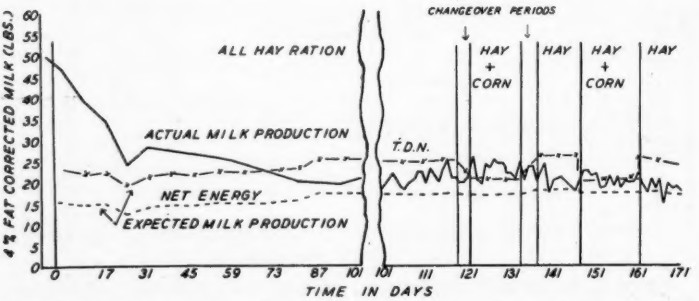

Figure 4. Actual milk production compared with expected milk production on a T.D.N. and net energy basis.

Beginning several weeks before the first changeover to hay plus a concentrate, milk production is shown on a daily basis for the remainder of the experiment. Expected milk production values represent weekly averages calculated from feed consumption and body weights.

An examination of figures 1 through 7 gives a graphic interpretation of the results. Each cow was changed from an all-alfalfa hay ration to hay plus a concentrate at periods of 173, 168, 176, 126, 153, 163, and 165 days respectively after parturition as shown in figures 1 through 7. The changes in net energy or in T.D.N. are reflected in the expected milk yield lines shown in each graph. The effect of feed changes upon milk production are shown in actual milk production curves. In only two instances, as shown in figures 3 and 6 did actual milk production rise above the milk yield expected on the basis of the net energy calculations. In figure 3 the excess milk yield during the hay plus distillers solubles feeding period may have resulted

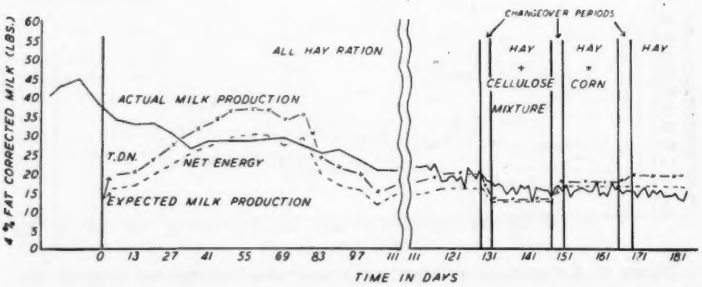

Figure 5. Actual milk production compared with expected milk production on a T.D.N. and net energy basis.

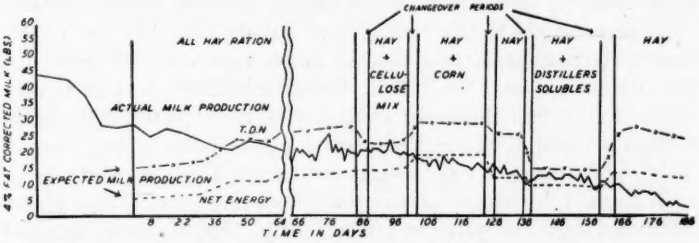

Figure 6. Actual milk production compared with expected milk production on a T.D.N. and net energy basis.

from an excess amount of energy fed as sugar and starch in the preceding experimental period. In figure 6, a small excess in milk production above that expected also resulted in the hay plus distillers solubles feeding trial. This increase is above the expected milk production on the net energy basis but below that expected on the T.D.N. basis. The increase is small, however, and considering the milk production graph alone this area appears as a normal decline. The remaining 14 hay plus concentrate feeding trials show no indication of increases in milk production when the calculations were made on the net energy basis.

A careful examination of figures 1 through 7 indicates that the expected milk production on a net energy basis predicted the actual milk production more accurately than T.D.N. Figure 4 is a possible exception to the above statement. In this figure, feed changeovers were made on an equal net energy basis. The actual milk production curve was approximately equidistant from the T.D.N. and net energy curves for expected milk production during the hay period and some-

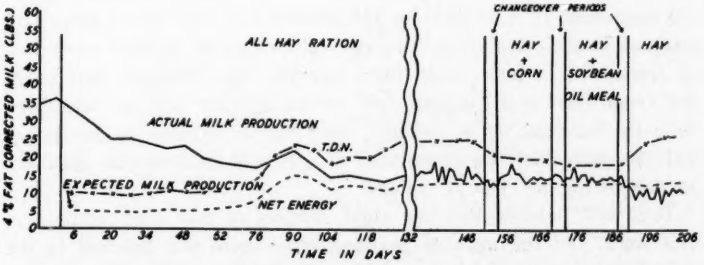

Figure 7. Actual milk production compared with expected milk production on a T.D.N. and net energy basis.

what closer to the T.D.N. curve during the corn feeding periods.

All seven of the figures tend to bear out the fact that the T.D.N. system overrates the feeding value of alfalfa hays. Also, the better the hay, the more closely the T.D.N. system approaches its true feeding value. This is best illustrated by observing the expected milk curves in figures 5 and 6. Figure 5 represents a good grade of hay (low in fiber) while figure 6 represents a poor grade (high in fiber).

In figure 3, a changeover was made from hay alone to hay plus a mixture of sugar and starch on a T.D.N. basis. This, of course, increased the net energy content of the ration. Actual milk production showed an increase above that expected on a T.D.N. basis but less than that expected on a net energy basis. Since this change and most of the changeovers from one type of ration to another were made during the later stages of lactation, milk increases would not be as great as expected because normal milk production as well as the capacity to increase milk production diminishes with time.

Discussion

These results show that the cows on an all-alfalfa hay ration produced about as expected on the basis of the calculated net energy intake and that when part of the hay was replaced by a concentrate such as corn, on a net energy basis, no significant increase in milk production was obtained. The results are in good agreement with the earlier report of Saarinen *et al.*

In most instances when the cows were on an all-hay ration, milk production leveled off at or very near the calculated expected milk production on a net energy basis. Despite the many known and unknown difficulties involved in the calculation of net energy, these values appear to be the most accurate estimate now available of the true feeding value of a ration when expected and actual milk production values are compared. It is realized by the authors that the use of proximate analyses in the calculation of energy values may be in error especially in feeds with a high crude fiber content. The chemical entities in the crude fiber and nitrogen free extract overlap and are contained in both fractions. It is believed that further studies in separating out the individual constituents of forages will increase the accuracy in calculating net energy values.

It is still possible that the eight samples of hay used to date in this work, and the work of Saarinen *et al.* were not deficient in the so-called factor(s). Such is considered unlikely, however, in view of the fact that recalculations of the data of Huffman and Duncan (1944,

TABLE 4. THE EFFECT ON MILK PRODUCTION IN CHANGING FROM HAY TO HAY PLUS A CONCENTRATE

(Recalculation on net energy basis of data in Table 3 from Huffman and Duncan 1950)

Trial No.	Feed intake Hay	Feed intake Suppl.	T.D.N. F.C.M. Yield	T.D.N. F.C.M. Incr.	Net energy F.C.M. expected[2]	
	lb.	lb.	lb.	%	lb.	%
			Beet Pulp			
1[1]	38.5	—	28.4	—		
	23.6	10.5	33.8	19.0	6.7	23.7
2	44.3	—	19.8	—		
	24.3	10.5	23.2	17.2	2.0	10.1
3[1]	33.8	—	18.5	—		
	24.0	7.0	22.3	20.5	6.1	33.0
4[1]	20.0	—	6.6	—		
	10.0	6.0	7.4	12.1	3.3	50.0
5[1]	24.0	—	7.6	—		
	14.0	6.0	10.2	34.2	3.3	43.4
6[1]	38.6	—	16.7	—		
	24.9	10.0	16.9	1.2	8.8	52.7
7[1]	29.1	—	12.4	—		
	9.8	10.0	13.6	9.7	3.0	24.2
8[1]	34.4	—	14.1	—		
	14.8	12.2	17.4	23.4	7.7	54.6
			Corn Gluten Meal			
11	43.4	—	21.1	—		
	38.0	3.0	26.1	23.7	3.2	15.2
	38.0	3.0	23.3	—		
	29.2	9.0	29.0	37.4	11.3	53.6
12[1]	35.0	—	13.1	—		
	25.0	6.0	16.0	22.1	4.9	37.4
13	32.8	—	15.5	—		
	14.0	6.0	19.0	22.6	1.9	12.3
14[1]	24.8	—	8.9	—		
	15.0	6.0	12.8	43.8	7.5	84.3
15	50.0	—	20.7	—		
	43.0	3.5	24.7	19.3	1.7	8.2
	43.0	3.5	24.8	19.8	1.4	6.8
16	32.8	—	9.8	—		
	26.8	3.0	12.5	27.6	1.6	16.3
17[1]	35.8	—	9.1	—		
	30.0	3.0	10.5	15.4	1.8	19.8
18[1]	44.3	—	26.0	—		
	42.1	6.0	24.4	—		
	43.1	6.0	26.4	8.2	15.3	58.8

(Continued on page 958)

(Continued from page 957)

TABLE 4. THE EFFECT ON MILK PRODUCTION IN CHANGING FROM HAY TO HAY PLUS A CONCENTRATE

(Recalculation on net energy basis of data in Table 3 from Huffman and Duncan 1950)

Trial No.	Feed intake		T.D.N. F.C.M.		Net energy F.C.M. expected[2]	
	Hay	Suppl.	Yield	Incr.		
	lb.	lb.	lb.	%	lb.	%
			Soybean Oil Meal			
19[1]	44.1	—	21.9	—		
	28.1	9.0	23.5	7.3	4.0	18.3
20	34.8	—	6.1	—		
	20.0	6.0	9.2	50.8	1.0	16.4
21	35.6	—	25.5	—		
	29.9	3.5	29.3	14.9	2.8	11.0

[1] Actual increases in milk lower than expected increases.
[2] All values are positive.
Trials 9 and 10 were not included because the analysis and digestion trial data for the concentrate involved were not given.

1949) by Saarinen *et al.* showed that in most cases the increases they obtained by replacing part of the hay with corn could be explained on the net energy basis.

A recent article by Huffman and Duncan (1950) showed increases in milk production in changing from hay to hay plus beet pulp, corn gluten meal or soybean oil meal. The replacement of hay with a concentrate was made on a T.D.N. basis. Using the Scandinavian method (Larson 1945) these data were recalculated on the net energy basis.

These recalculations as given in table 4 show that in 14 out of the 21 trials, increases in milk production could be explained on the net energy basis, whereas there was an increase in 7 out of 21 trials above that expected on the net energy basis. Of these 7 trials, however, only trial number 20 showed a marked increase above that expected on the basis of the net energy calculations.

The differences between the results obtained by Huffman and Duncan (1950) and the results reported herein as well as those obtained by Saarinen *et al.* appear to be due primarily to the system used in the evaluation of the feedstuffs. While some alfalfa hays may be deficient in certain factor(s) needed for milk production, the data published to date do not appear to show such a deficiency.

Summary and Conclusions

Seven cows were fed hay and hay plus concentrate rations to observe the effect of these rations upon milk production. Four lots of hay and six different concentrates were fed. Thirty-two different test periods were studied consisting of 16 all-hay periods and 16 hay plus concentrate periods.

No marked increases were observed in milk production when part of the hay was replaced by ground corn, cellulose mix, cornstarch, cane sugar, distillers solubles and soybean oil meal which could not be explained on a net energy basis.

The actual milk production of cows on an all-alfalfa hay ration was much closer to that expected on the basis of net energy calculations than that expected on the basis of T.D.N. calculations.

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THE EFFECT OF SPRINKLING ON THE RESPIRATION RATE, BODY TEMPERATURE, GRAZING PERFORMANCE AND MILK PRODUCTION OF DAIRY CATTLE[1]

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PREVIOUS studies in Louisiana (Seath and Miller, 1947a, 1947b, 1947c) indicated that dairy cows spend much of the daytime during the summer in the shade in comparative inactivity and that body temperatures and respiration rates increase progressively throughout the day. Other experimental work (Hays, 1926; Ragsdale and Turner, 1922; and Regan and Richardson, 1938) has shown that milk production and butterfat percentage fall when environmental temperatures rise above the point at which thermal neutrality between the cow and the environment no longer exists.

Summer comfort of cows may be provided in various ways. Bathing and splashing has long been a common practice in the Orient (Minett, 1947; and Phillips, 1945). Sprinkling with water to increase evaporation from the skin was effective in lowering body temperature and respiration rate (Brody, 1946; Ittner and Kelly, 1948; Seath and Miller, 1947b, 1948a, 1948b). Air movement produced by a fan also has been shown to be useful in cooling dairy cows (Seath and Miller, 1948a). Shade, either natural or artificial, is very important in hot weather. Artificial shades of different types have been studied in California (Ittner and Kelly, 1948); hay covered shades and aluminum shades cut off more of the suns heat than the galvanized iron shades and wood slat shades.

This experiment was undertaken to study the effect of sprinkling dairy cows with water on the respiration rate, body temperature, grazing performance, and milk production during the summer months.

Experimental Procedure

Two comparable groups of 16 cows each (8 Holsteins and 8 Jerseys) were used in a double reversal experiment with 3 periods of 14 days

[1] A contribution of the Dairy Department. Published with the approval of the Director of the Louisiana Agricultural Experiment Station.

[2] The data in this paper are from a thesis submitted by the senior author to the Graduate School of Louisiana State University in partial fulfillment of the requirements for the degree of Master of Science, 1949.

each and a 2 day change-over between periods. Each group of cows was fed and managed in the same manner except that one group was given access to shade, while the other group was provided with a shower bath in addition to the shade. The animals were subjected to one of these two treatments from about 7 a.m. until 2:30 p.m. at which time they were driven to the milking barn. Twelve sprinklers, which were installed in the ceiling of a shed (15′ x 30′), provided the shower in the form of a fine mist spray.

Atmospheric temperatures were recorded at approximately 2:30 p.m. each day. Respiration rates secured from counts of flank movements

TABLE 1. EFFECT OF ENVIRONMENTAL TEMPERATURE ON TIME SPENT UNDER SPRINKLER BY JERSEYS AND HOLSTEINS SHOWING SIGNIFICANCE BETWEEN TEMPERATURE RANGES WITHIN BREEDS[1]

Temperature range[2] (°F.)	Number observations	Average time under sprinkler					
		Holsteins		Jerseys		Average	
		Minutes	Increase[3]	Minutes	Increase	Minutes	Increase
			(%)		(%)		(%)
80–85	5	84		79		82	
86–91	9	189	125**	173	118*	181	122*
92–97	11	293	253**	216	173**	255	218**
Av.		214		173		194	

[1] Average time in pasture 450 minutes.
[2] Maximum temperature on day of observation.
[3] Increase over observations made at temperature range 80° to 85° F.
* P=0.05
** P=0.01

were recorded during the first 14-day period. Body temperatures which were taken by inserting a veterinary thermometer approximately 4 inches into the rectum were recorded immediately after entering the barn when the weather was warm enough to cause higher than normal temperature in the cow. Respiration rates and body temperatures were taken in the pasture and again in the barn on several days for comparative study. Pasture performance of the cows during the daytime was observed and recorded. Daily milk production records were kept. Butterfat tests were made weekly and the milk converted to a 4 percent fat corrected value.

Results and Discussion

Relationship between Air Temperature and Use of the Sprinkler

A definite relationship between air temperature and time spent under the shower was noted (table 1). Although both breeds used the

shower more as the temperature increased, the Holsteins remained under the shower an average of about 9 percent more of the time than did the Jerseys during the entire study. This indicates that the Holsteins were not quite as efficient in maintaining normal body temperature as were the Jerseys. It is noteworthy that the time spent under the shower for both breeds more than doubled (122% increase) when the maximum temperature increased from a range of 80° to 85° F. to a range of 86° to 91° F. Statistically (Snedecor, 1946) this increase was significant for the Holsteins at the 1 percent level and at the 5 percent level for the Jerseys. The animals spent approximately 3 times (218% increase) as much time under the shower when the temperature ranged from 92° to 97° F. as they did when the temperature ranged from 80° to 85° F. This difference in time was highly significant for both breeds. The greatest increase in the amount of time spent under the shower was noted with the Holsteins. For instance, the amount of time spent under the shower by the Holsteins was 253% greater at a temperature range of 92° to 97° F. than it was at a range of 80° to 85° F. The increase for the Jerseys was 173%. The difference between the Holsteins and Jerseys was not significant until the highest range of temperatures, 92° to 97° F., was reached. At this temperature range the greater use of the shower by the Holsteins was highly significant.

Respiration Rates

Respiration rates were taken on 10 relatively warm days (average maximum temperature 93° F., range 88° to 97° F.) in the pasture just before the animals departed for the milking barn and again after they had walked one-fourth of a mile to the barn. While in the pasture the respiration rates of the Holsteins and Jerseys having access to shade were 90 and 92 per minute, respectively. The respiration rates of the Holsteins and Jerseys having access to the shower were 74 and 80, or 18% and 13% lower, respectively, than those with shade. The difference between breeds with only shade was not significant (Snedecor, 1946) but when provided with the shower the differences in respiration rates were highly significant. Within breeds the results showed a significant lowering of respiration rates among the Jerseys and a highly significant decrease in the Holsteins when the shower was available. These data indicate that sprinkling was effective in reducing respiration rate and was of the greatest value for the Holsteins. After walking to the barn the respiration rates of the Holsteins with shade increased from 90 to 98 respirations per

minute or 9.5%, while those of the cows with the shower increased from 74 to 96 per minute, or 30.5%.

After the same trip the respiration rates of the Jerseys with shade increased from 92 to 105 per minute or approximately 15% and those of the Jerseys with the sprinkler increased from 80 to 98 per minute or approximately 24%. The cows that had access to the shower and shade had lower respiration rates than those with only shade when in the pasture but this difference was largely overcome by the time they had made the trip to the barn. These records show the Jerseys had higher respiration rates under all conditions. This may mean that the Jerseys can make greater use of respiration as a means of cooling the body.

Body Temperature

Body temperatures of the cows were taken upon entering the barn on the same days that respiration counts were made. When provided with only shade the Holsteins and Jerseys had an average body temperature of 103.8° F. and 103.3° F. (average maximum air temperature 93° F.), respectively. When the shower was available the average body temperature of the Holsteins and Jerseys was 103.1° F. and 102.9° F., respectively. The differences between breeds were not great for either treatment. Using analysis of variance (Snedecor, 1946), it was found that in the case of cows with only shade the variance between breeds, though small, was highly significant. When sprinkling was available there was no significant difference for temperatures between breeds. Although the cows of each breed which had the shower showed on the average lower body temperatures than those with only shade the variance between treatments was significant for the Holsteins only. In either case the Holsteins had the higher body temperatures, but the reverse was true for respiration rates on the same day. Other workers have reported similar results (Seath *et al.*, 1947a). Brody *et al.* (1949) reported that Holsteins and Jerseys had an average body temperature of 107.7° F. and 105.6° F., respectively, when the air temperature was 100° F., while their respiration rates were 100 and 130 per minute for the Holsteins and Jerseys, respectively. However, body temperature may have less relationship to milk production than does respiration. Rhoad (1936) suggested from his study of the influence of environmental temperature on the respiratory rhythm of dairy cattle in the Tropics that "the loss of energy in dairy cattle as the result of high temperature is in a large

way responsible for the low production of European dairy cattle in the Tropics." The question arises as to whether or not the high body temperature of the Holsteins is due to their lower respiration rate. Although the faster respiration rate of the Jerseys requires greater production of energy with its increment of heat, there appears to be an overall cooling effect due to the increased respiratory ventilation.

When body temperatures of cows, selected at random regardless of treatment, were taken in the pasture and again after being driven to the barn on 10 warm days (average maximum air temperature 93° F., range 88° to 97° F.) an average increase of only 0.5° F. for each of the breeds occurred. This is in line with the results of other work done in Louisiana (Seath *et al.*, 1948) showing that body temperature is slower to respond to changes in air temperature than is respiration rate. This small rise in body temperature may not be very important, but it does show a consistent trend toward higher body temperature for all the cows after a short drive of one-fourth of a mile. Longer trips from the pasture to the milking barn might result in sufficient rise in body temperature to cause the cows to suffer.

TABLE 2. EFFECT OF ENVIRONMENTAL TEMPERATURE ON GRAZING PERFORMANCE OF COWS WHEN PROVIDED WITH SHADE OR SHOWER[a]

Temperature range[1] (°F.)	Number of observations	Grazing Time							
		Animal with access to shade				Animal with access to shower or shade[3]			
		Holsteins		Jerseys		Holsteins		Jerseys	
		Time	Dec.[2]	Time	Dec.	Time	Dec.	Time	Dec.
		%	%	%	%	%	%	%	%
80–85	5	63		63		63		63	
86–91	9	30	52**	34	46**	35	44**	36	43**
92–97	11	20	69**	20	68**	24	62**	26	58**
Av.		32		34		36		37	

[1] Maximum temperature on day of observation.
[2] Decrease in grazing rate compared with that at temperature range 80° to 85° F.
[3] These animals had a choice of shade or shade plus the shower.
* P=0.05
** P=0.01
[a] The apparent discrepancy between time spent under sprinkler shown in table 1 plus time spent grazing shown in table 2 and total time in the pasture is due to the fact that part of the time the cows were under the dry shade.

Grazing Performance

Data presented in table 2 reveal a pronounced effect of high temperatures on the grazing performance of Jerseys and Holsteins. When the temperature range was 80° to 85° F. both breeds spent 63% of

their time grazing and the use of the shower appeared to have no significant effect on grazing rate. However, as the temperature increased from 86° to 91° F. the grazing rates of the Holsteins and Jerseys provided with shade were reduced 52 and 46%, respectively, and those with the shower decreased 44 and 43%, respectively, in grazing rate. When the temperature reached 92° to 97° F. the grazing rates of the Holsteins and Jerseys with shade dropped 69 and 68% and those with the shower dropped 62 and 58%, respectively, as compared with that at a temperature range of 80° to 85° F. These decreases in grazing rate at the higher temperatures were highly significant within each of the breeds, regardless of treatment, but the variance between breeds was not significant for either treatment at any of the temperatures. The significant differences were found within breeds only. The variance between treatments within the Jerseys was smaller at all temperature ranges than that of the Holsteins and was significant at the 5% level at the highest range only. The Holsteins showed a highly significant difference between treatments at the 92°–97° F. range but no significance at lower temperatures.

These data indicate that the Holstein will graze as much as the Jersey at comfortable temperatures, but when the environmental temperature rises above the cow's comfort zone the Jersey will graze more than will the Holsteins until extremely high temperatures occur when again there is little difference. Even when the animals were using the shower the Holsteins did not graze quite as much as did the Jerseys, but apparently the use of the shower enabled the Holsteins to graze almost as much as did the smaller breed. During the hottest days the animals having access to the shower would venture from the shade occasionally and graze for a few minutes, while cows without the shower remained in the shade throughout the day.

Since the shower was effective in cooling the cows as evidenced by decreasing respiration rates and body temperatures and increasing grazing rates one would expect it to reflect in the amount of milk produced. However, there appeared to be no relationship between the amount of milk produced and the treatment. The t value was not significant for treatments for either breed. It is highly probable that the grazing time lost during the day was compensated for during the night. If this occurred, the effect of the treatment if any, on milk production may have been counteracted. Although the cows grazed more as the result of the sprinkling it is quite possible that the pasture was not sufficiently good in quality to stimulate the production of an additional amount of milk. It may be that the additional

grazing resulted in a gain in liveweight rather than in an increase of milk production. Consequently, future studies of this type should include the following: (1) grazing observation during a 24 hour period, (2) nutritional evaluation of all feeds consumed and (3) liveweight trends during the study. Furthermore, the study should be conducted during a time when temperatures are persistently above the critical temperature of 85° F.

Summary and Conclusions

Two groups of 16 lactating cows (8 Holsteins and 8 Jerseys) each were used in a double-reversal experiment to study the effect of cooling by sprinkling on respiration rates, body temperatures and grazing performances. Although both breeds used the shower more as the temperature increased, the Holsteins remained under the shower an average of about 9 per cent more than did the Jerseys. The average amount of time spent under the shower for both breeds was 2 and 3 times as great at a temperature range of 85° to 90° F. and 92° to 97° F., respectively, as at a temperature range of 80° to 85° F.

Respiration rates were slightly higher for Jerseys than for Holsteins, while the reverse was noted for body temperatures. The respiration rates of Holsteins and Jerseys having access to the shower were 18 and 13 percent lower, respectively, than for those with only shade. However, the respiration rates of the two groups were very nearly the same after walking one-fourth of a mile to the barn.

Sprinkling was effective in producing a lower body temperature for both breeds. Holsteins and Jerseys being sprinkled had body temperatures of 0.7° F. and 0.4° F. lower, respectively, than did those with only shade. After walking one-fourth of a mile to the barn there was an average increase of 0.5° F. for each of the breeds, irrespective of treatment.

When the temperature range was 80° to 85° F. both breeds spent 63% of their time grazing and the use of the shower appeared to have no significant effect on grazing rate. The grazing rate decreased as the temperature increased. At a temperature range of 92° to 97° F. the Holsteins and Jerseys grazed 69 and 68% less, respectively, than they did at a range of 80° to 85° F.

Although sprinkling was effective in cooling the cows as evidenced by decreasing respiration rates and body temperature and increasing grazing rates, there appeared to be no relationship between the amount of milk produced and treatment.

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SOME PHYSICAL CHARACTERISTICS OF THE TISSUE AND CONTENTS OF THE RUMEN, ABOMASUM AND INTESTINES IN MALE HOLSTEIN CALVES OF VARIOUS AGES[1, 2]

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RELATIVELY little data has been accumulated concerning the physical characteristics of the tissues and contents of the digestive tract of the dairy calf. Further information is needed about the weights and capacities of various parts of the tract and the changes which occur in the tissues and in the digestive contents with advancing age. With increasing emphasis and importance being placed upon the functions of the rumen in bovine nutrition, it becomes increasingly important to study the development of this organ in the young animal. Dukes (1947) states that in the newborn calf the rumen is small, the abomasum being about twice as large as the rumen and reticulum combined. At the age of 4 months the rumen is 4 times the size of the abomasum. Marshall *et al.* (1950) reported that the weight and volume of rumen tissue and weight of fresh contents exceeded that of the abomasum between 7 and 30 days of age. These authors also presented data on the pH of the various stomach compartment contents in young calves. Parrish and Fountaine (1950) presented weights of alimentary contents along with pH, dry matter and the results of various analyses on the meconium taken from calves at the time of birth. Recently Becker *et al.* (1951) reported on the development of the bovine stomach during fetal life.

This report presents observations on some of the characteristics of stomach and intestinal contents and tissues of male Holstein calves made at the time of slaughter. The data cover a series of three trials, with animals varying in age from 8 days to 16 weeks.

Experimental

Male Holstein calves were purchased from various Pennsylvania institutional herds and brought to an experimental barn. Feeding and

[1] Taken from data presented in theses to the graduate faculty of The Pennsylvania State College by E. M. Kesler and by M. Ronning in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

[2] Authorized for publication as paper No. 1650 in the Journal series of the Pennsylvania Experiment Station.

management were identical for all of the calves in the first two trials. Each had received colostrum then was placed on a milk feeding schedule which would permit consumption of 270 pounds of Holstein herd milk during the first 36 days of life. Medium grade alfalfa hay was before these animals at all times and a calf starter was fed *ad lib.* up to a maximum of 5 pounds per calf daily.

In one series 4 groups of 5 calves each were sacrificed at the ages of 8, 16, 24 and 32 days respectively, this series being designated as trial I. Another lot, called trial II, were slaughtered with 3 calves in each of the following age groups: 2, 4, 6, 8, 10, 12, 14 and 16 weeks. All animals of these groups were slaughtered at time intervals of 4 to 6 hours after feeding. A record was made of body weights at birth and at slaughter. After the animal was slaughtered, the rumen and reticulum were emptied. The contents were weighed and their odor, appearance and consistency were noted. Next the rumen was freed of extraneous material and the weight of the tissues was recorded. In trial I the weight of the abomasum contents and tissues also were recorded, and the approximate size of the omasum was noted. The pH of the fresh contents of the rumen, abomasum, small intestine and large intestine of those calves in trial I was measured using a pH meter.

Similar observations were made on another group of calves (trial III) which had a controlled dietary intake. These calves received colostrum for one day, and then were placed on a diet consisting of three pounds of skimmilk and two pounds of a whole milk replacement which was fed twice daily. No additional fluids or dry feeds were made available. The calves were kept on wire screens over straw, to prevent consumption of bedding. After seven days under this management these calves were slaughtered eight hours after the last feeding. The digestive tract tissues and contents were weighed, and the pH and percent dry matter of the contents were determined.

Results and Discussion

A summary of the findings in trial I is presented in table 1. This trial included 20 animals which had been fed a normal diet of grain, hay and milk until slaughtered at the ages of 32 days or younger. The data indicate that the weights of rumen tissue and of the rumen contents increased slowly but steadily with advancing age. This indicates that rumen development begins at an early age. As shown in table 1, there were no appreciable differences in the weights of

TABLE 1. BODY WEIGHT, STOMACH TISSUE AND CONTENTS WEIGHTS AND PH OF DIGESTIVE CONTENTS OF CALVES IN TRIAL I[1]

Age Group (days)	Body wt. at slaughter (lb.)	Gain in Body wt. over initial (lb.)	Rumen			Abomasum			pH of Small Intestine Contents	pH of Large Intestine Contents
			Wt. of Tissue (lb.)	Wt. of Contents (lb.)	pH of Contents	Wt. of Tissue (lb.)	Wt. of Contents (lb.)	pH of Contents		
8	100.3	2.3	0.4	0.7	5.58	0.6	1.9	4.05	6.35	6.06
16	105.7	4.3	0.5	2.0	5.54	0.6	2.1	3.41	6.23	6.23
24	100.2	8.4	0.6	2.0	5.51	0.6	1.3	3.74	6.32	6.50
32	119.3	13.9	0.7	3.2	5.60	0.6	1.8	3.66	6.42	6.67

[1] Data presented are the mean of 5 calves in each age group.

abomasum tissue and contents between age groups. The data show that the pH of the digestive contents of the calves was acidic, with the lowest pH in the abomasum material followed in order by rumen and intestinal contents. No pH differences due to age were noted except for some indication of decreasing acidity in the large intestine contents with advancing age.

Data obtained in trial II are presented in table 2. Results for calves 2 and 4 weeks of age were approximately the same as obtained for similar aged animals in trial I. Steady increases in the weights of both tissue and contents were evident with advancing age. A marked

TABLE 2. WEIGHTS OF BODY, RUMEN TISSUE AND RUMEN CONTENTS OF CALVES IN TRIAL II[1]

Age group (weeks)	Body wt. slaughter (lb.)	Body wt. over initial (lb.)	Rumen tissue (lb.)	Rumen contents (lb.)
2	100.3	1.0	.5	.8
4	107.3	12.0	.6	1.7
6	130.5	34.8	1.6	9.2
8	143.8	48.5	2.1	13.3
10	169.5	69.8	3.1	15.5
12	193.5	98.8	3.7	19.7
14	207.8	108.8	3.9	21.9
16	247.2	148.7	5.1	22.8

[1] Mean of 3 calves in each age group.

increase in these weights occurred between the ages of 4 and 6 weeks. Coefficients of correlation were run on the data obtained in this trial. A highly significant correlation of r=0.983 (standard error=0.039) was obtained between body weight of the calf and weights of rumen tissue. An r value of 0.908 was found between body weight and weight of rumen contents, this value being also highly significant and with a standard error of 0.089. Gain in body weight showed a highly significant correlation of r=0.900 to weight of rumen contents. The standard error of this correlation was 0.093. All correlations were computed from the individual data obtained for each calf.

The results of the third study are summarized in table 3. This group of calves had somewhat lower initial weights than the 8 day group in the previous observations and exhibited a loss in weight. While the tissue weights of the rumen are comparable to those observed in trial I, the weight of the contents are higher. This could perhaps

be attributed to the liquid diet. At this age it appears that the weights of the tissues of the rumen, abomasum and large intestine are nearly the same, whereas the small intestine is two to three times as heavy. The percent dry matter of the rumen contents was about one half of that observed in the contents of the abomasum and in the ingested feed. This might indicate a freer passage of liquid into the rumen during ingestion or a tendency toward retention of the liquids during the passage of the material from the rumen to the abomasum. The average percent dry matter of the ingested feed was 9.16. The contents of the digestive tract were acid in all instances, although in the small and large intestines neutrality was approached.

TABLE 3. WEIGHTS OF DIGESTIVE TRACT TISSUES, AND WEIGHTS, pH AND % DRY MATTER OF DIGESTIVE TRACT CONTENTS OF CALVES IN TRIAL III[1]

Section	Tissue	Contents		
	Weights (lbs.)	Weights (lbs.)	pH	% D. M.
Rumen	0.44	0.99	4.09	4.71
Abomasum	0.41	1.53	3.22	8.26
Small Intestine	1.66	0.94	5.93	7.55
Large Intestine	0.53	0.43	5.72	7.71

[1] Means of 15 calves.
Average Initial weight of calves—96.2 lbs.
Average Slaughter weight of calves—94.0 lbs.

Observations were made at the time of slaughter on the appearance, consistency and odor of the rumen contents, which, in the older animals, consisted of a mass of greenish brown material, made up mostly of roughage with characteristics similar to those of the adult bovine. Very little free liquid was present, the contents usually were of medium fineness in consistency and a typical adult rumen odor was present. All animals 6 weeks of age or older had rumen contents showing these adult-like characteristics. Calves less than 6 weeks of age were variable with some presenting the beginnings of the development of the above described types of contents. However most of these younger animals had paunch contents which were composed of a few strands of long hay, liquid which was gray to yellow-brown in color and presented a foul odor. Between the ages of 32 days and 6 weeks the type of rumen contents changed, becoming more like that found in the adult rumen.

In the group of calves on the controlled dietary intake, the rumen

contents had the same sour, sewer-like odor observed in the first trials. The large intestine presented characteristic odors associated with the decomposition of protein material. The remainder of the tract was practically odorless, with the abomasum having a trace of a whey odor and the small intestine presenting a light yeasty aroma.

Summary

A total of 59 calves were slaughtered at ages varying from 8 days to 16 weeks. Mean weights of rumen contents and tissues are presented. A pronounced increase in these weights occurred between the ages of 32 days and 6 weeks. A change in the characteristics of the rumen contents occurred by the age of 6 weeks and it appeared that rumination, as measured by the criteria of this experiment, had begun at this age. Mean weights of tissue and contents are presented for other parts of the digestive tract for the young calves, along with pH, dry matter and other observations on the nature of the contents.

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THE SUPPLEMENTATION OF MILK REPLACEMENTS WITH ENZYMES AND OTHER PRODUCTS[1]

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MILK replacement formulae have been developed which have produced growth in dairy calves comparable to that of milk fed calves managed according to recommended procedures, Williams and Knodt (1949, 1950).

Conquest *et al.* (1938) added pancreatin and papain concentrates and produced a milk that did not stay in the stomach of the calf as long as did normal pasteurized milk. Flipse *et al.* (1948, 1949, 1950) used synthetic milks in raising young dairy calves and found that lactose was superior to corn syrup and glucose and that a corn syrup-lactose combination produced better growth than starch-lactose or starch alone. These authors have also compared corn starch, dextrin and corn sugar as the principal carbohydrate source in synthetic rations for calves and found that corn sugar fed calves had more finish and less scours than the dextrine or starch fed calves.

The experimental work presented in this report involved studies of the supplementation of formulae developed previously with enzyme preparations such as pancreatin powder and papain powder as well as condensed fish solubles, butyl fermentation solubles, and a carbohydrate product (20.8% dextrose, 32.9% maltose, 42.8% dextrin and 3.5% water).

Experimental

Trial One

Eighteen male Holstein calves were obtained from Pennsylvania State Institutional herds and divided into three comparable groups on the basis of body weight, withers height and chest circumference. They were housed and managed as described previously, Williams and Knodt (1950). The calves were fed the formulae in table 1 at 100° F. according to the schedule presented in table 2.

The calves were also fed a good quality grass-legume hay *ad libitum* and were fed a maximum of 6 pounds daily of the calf

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TABLE 1. PAPAIN AND PANCREATIN POWDER MILK REPLACEMENT FORMULAS

(Trial I)

Ingredient	Group		
	I (lb.)	II (lb.)	III (lb.)
Dried Skimmilk	50	50	50
Dried Whey	10	10	10
Distillers Dried Solubles	10	10	10
Blood Flour	10	10	10
Oat Flour	5	5	5
Dextrose	7.75	7.75	7.75
Brewers Dried Yeast	4.90	4.90	4.90
Irradiated Yeast (9F)	0.10	00.10	0.10
Stabilized Vitamin A Feed[1]	0.22	0.22	0.22
Mineral Mixture[2]	0.042	0.042	0.042
Dicalcium Phosphate	2.50	2.50	2.50
Papain Powder		200 g.	50 g.
Pancreatin Powder	200 g.		

[1] The supplement contained 2,220,000 USP units/pound.

[2] Mineral Mixture: Ferric Citrate ($FeC_6H_8O_7 \cdot 3H_2O$) 56.75%
Cupric Sulfate ($CuSO_4 \cdot 5H_2O$) 19.73%
Manganese sulfate ($MnSO_4 \cdot 4H_2O$) 21.59%
Cobalt Chloride ($CoCL_2 \cdot 6H_2O$) 2.11%

starter presented in table 3 in mash form. Growth measurements were taken weekly by the same person who also made daily observation of the physical condition of the feces.

Trial Two

Thirty-six calves from the same sources were divided similarly into six comparable groups and fed the milk replacement formulas in table 3 at 100° F. according to the schedule presented in table 4.

TABLE 2. MILK REPLACEMENT FEEDING SCHEDULE FOR TRIAL 1

Days of Age	Whole milk lb.	Replacement lb.	Water lb.
1–4	4 (Colostrum)[a]		
5–7	4 (whole milk)[a]		
8–21		0.3[a]	4[a]
22–28		0.4[a]	4[a]
29–42		0.5[a]	5[a]
43–49		0.6[a]	6[a]
50–56		0.6[b]	6[b]

[a] Twice daily
[b] Once daily

TABLE 3. MILK REPLACEMENT FORMULAE (TRIAL II)

Item	Group					
	I (lb.)	II (lb.)	III (lb.)	IV (lb.)	V (lb.)	VI (lb.)
Dried Skimmilk	45	55	65	65	43	40
Dried Whey	10	10	10	10	10	10
Dist. Dried Solubles	15	15	15	20	15	15
Blood Flour	10	10			10	10
Oat Flour	5	5	5		5	5
Carbohydrate Product	10				10	10
Fish Solubles, (Cond.)					2	
Butyl Ferm. Sol.						5
Vitamin Conc.[1]	.5	.5	.5	.5	.5	.5
Mineral Conc.[2]	2.00	2.00	2.00	2.00	2.00	2.00
Dicalcium Phosphate	2.50	2.50	2.50	2.50	2.50	2.50

[1] (500D_2—4000A per gram)—contributed by Nopco Chemical Corp., Harrison, N. J.
[2] Mineral mix contains: Calcium 32%, Magnesium 2.6%, Manganese 1%, iron 0.175%, iodine 0.225%, copper 0.125% and cobalt 0.002%—contributed by Limestone Products Corporation of Newton, N. J.

All groups of calves were fed alfalfa hay *ad libitum* during the 12 week trial. The calf starter presented in table 5 was fed up to a maximum of 6 pounds daily per calf. Calves 1 and 4 in each group received the starter in mash form, calves 2 and 5 in pellet form and calves 3 and 6 in crumble form. The crumble form was prepared by breaking the three-eighths inch pellets into 5 to 10 fragments mechanically.

Results and Discussion

Trial One

The calves fed on the enzyme preparations made poor gains as

TABLE 4. MILK REPLACEMENT FEEDING SCHEDULE FOR TRIAL 2

Days of Age	Whole milk lb.	Replacement lb.	Water lb.
1–4	4 (colostrum)[a]		
5–7	2[a]	0.2[a]	2[a]
8–10	1[a]	0.4[a]	3[a]
11–21		0.5[a]	5[a]
22–35		0.6[a]	6[a]
36–49		0.7[a]	7[a]
50–56		0.7[b]	7[b]

[a] Twice daily
[b] Once daily

TABLE 5. CALF STARTER FORMULA (LB.)

Ground Yellow Corn	416.5
Wheat Bran	300
Crimped Whole Oats	400
Linseed Oil Meal	100
Soybean Oil Meal (44%)	300
Dehydrated Alfalfa Meal	150
Cane Molasses	100
Dried Skimmilk	100
Distillers Dried Corn Solubles	100
Irradiated Yeast (9F)	0.5
Dicalcium Phosphate	10
Ground Limestone	10
Iodized Salt	10
Vitamin A Feeding Oil[1]	3

[1] 2,270,000 U.S.P. Units per pound in dry meal form.

shown in the growth and feed consumption data in table 6. Two of the six calves that received the higher level of papain died early in the trial and post-mortem examinations revealed severe dehydration and intestinal degeneration. The other calves in the group as well as those in groups I and III had very rough hair coats and were unthrifty generally. Calf starter consumption was below normal and very little hay was consumed during the 49 day trial. Analysis of variance demonstrated that the papain fed groups grew at faster rates ($P<0.01$) as compared to the pancreatin fed group in terms of body weight and chest circumference. No significant difference in growth in terms of height of the withers was found between groups. On the basis of these results and the growth rates obtained (table 6) it does not appear that papain powder or pancreatin powder were of value as supplements under the conditions studied.

TABLE 6. MEAN DAILY GAIN IN BODY WEIGHT, WITHERS HEIGHT AND CHEST CIRCUMFERENCE AND AVERAGE CONSUMPTION OF CALF STARTER. (TRIAL I)

Group	Mean daily gains			Calf Starter Consumption
	Body Wt. (Lb.)	Ht. (Cm.)	Chest Circ. (Cm.)	Average (lb.)
I (Pancreatin fed)	0.30	0.08	0.05	28
II (Papain fed)	0.59	0.08	0.10	47
III (Papain fed)	0.67	0.08	0.10	38

Trial Two

The calves in groups I, V and VI receiving the carbohydrate material described previously instead of dextrose, were below normal in growth as well as in feed consumption as shown in table 7. It is not believed that the poor growth of groups V and VI could be explained on the basis of the inclusion of fish solubles or butyl fermentation solubles but rather on the basis of the carbohydrate material fed. Similarly, groups II and III which received milk replacements without dextrose did not make normal gains even though these formulae were similar to those which had produced normal growth in previous experiments. The calves in group IV attained normal growth on a

TABLE 7. MEAN DAILY GAINS IN WEIGHT, HEIGHT AND CHEST CIRCUMFERENCE AND AVERAGE CALF STARTER AND HAY CONSUMPTION (TRIAL II)

Group	Mean Daily Gains			Feed Consumption	
	Wt. (lb.)	Ht. (Cm.)	Chest Circ. (Cm.)	Starter (lb.)	Hay (lb.)
I (Carbohydrate product)	0.93	0.106	0.20	164	25
II (No Carbohydrate product)	1.00	0.11	0.18	154	29
III (No blood flour)	0.75	0.08	0.18	137	13
IV (High skimmilk)	1.20	0.14	0.20	207	18
V (Fish Solubles)	1.00	0.095	0.18	135	25
VI (Butyl Ferm. Sol.)	1.00	0.10	0.18	181	11

relatively simple formula composed of dried skimmilk, dried whey, distillers dried solubles and sources of vitamins A and D and certain mineral elements. Such a formula would, under certain market conditions, be of value as a milk replacement for raising dairy calves.

When all groups in trial 2 were compared on the basis of statistical analysis, it was found that group IV grew at a faster rate ($P<0.01$) in terms of body weight and height at the withers than any of the other groups. There were no significant differences in growth rates between groups I, II, V and VI while group III grew at the slowest rate ($P<0.01$) of any of the groups studied.

Summary

The addition of papain powder and pancreatin powder to the milk replacement used, was deleterious in that growth was poor, feed consumption was low and dehydration and intestinal degeneration were evident on post mortem examination of the two fatalities.

Growth was below normal in the groups that received a dextrose-maltose-dextrin carbohydrate material at the 10 percent level. The addition of butyl fermentation solubles at the 5 percent level or condensed fish solubles at the 2 percent level did not enhance growth under the conditions studied.

A relatively simple formula of dried skimmilk, distillers dried solubles, dried whey with sources of vitamins A and D and essential mineral elements gave normal growth in the calves used in these experiments.

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AN EOSIN-NIGROSIN STAIN FOR DIFFERENTIATING LIVE AND DEAD BOVINE SPERMATOZOA

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VARIOUS staining mixtures for differentiating live and dead spermatozoa have been proposed since the original report of this technique by Lasley *et al.* (1942). Since the background stain (opal blue) used in their method was not available during the war, mixtures using fast green were reported satisfactory by Mayer *et al.* (1947) and aniline blue and eosin were successfully used by Shaffer and Almquist (1948). The proper staining of dead sperm was found by Mayer *et al.* (1951) to depend upon careful control of pH, osmotic pressure, stain concentration and ionizable salts. Emik and Sidwell (1947) had found that pH, stain concentration, and time of staining and drying affected results with eosin-opal blue used on ram semen.

A different staining method for differentiating live and dead bull spermatozoa was proposed by Blom (1950) using eosin as the sperm staining substance and nigrosin as the background stain. This mixture gave a very uniform preparation with stained (dead) cells clearly distinguishable from the live or unstained cells. The nigrosin provides a smoother background stain than fast green, opal blue, or aniline blue. It seems to obscure the sperm less and mixes with seminal plasma or diluter more uniformly. For this reason it can be used as easily with egg-yolk diluted semen as with semen not mixed with egg yolk. The nigrosin background stain also very clearly shows certain morphological characters such as protoplasmic droplets and abnormal acrosomes as reported by Hancock (1947). Hence, it provides an improved preparation for checking morphological variations from the live-dead stain.

It was readily apparent in early trials with Blom's (1950) method in this laboratory that the results were not the same on many samples of semen as were secured with the method of Mayer *et al.* (1947). Therefore an investigation was made concerning the use of eosin and nigrosin for staining bull semen in order to obtain results comparable to other proven methods.

Experimental

Semen for this investigation was secured from bulls in the University of Tennessee dairy herd. The semen specimens used included

fresh and stored pure semen and fresh and stored diluted semen. The diluter used was 3 to 4 parts of 3 percent sodium citrate (dihydrate) solution and 1 part of fresh egg yolk.

Smears were prepared with the mixed stain solutions by mixing one large drop of stain with one very small drop of representative semen (proportions about 10 to 1) on a clean glass microscope slide with a glass stirring rod. A clean microscope slide was placed over the mixed stain and semen. The mixture was uniformly distributed between the slides; then they were drawn apart quickly and immediately dried on a warm plate in a strong current of air. The unmixed stain was used according to Blom's method except that the slide was dried immediately after preparation in the same manner as the other stains. Percentage of dead sperm was determined from examination of not less than 300 sperm per slide under the oil immersion objective.

All solutions were prepared with pure water, doubly distilled over glass. The isotonic buffer solution in which the dyes were dissolved was 3 percent sodium citrate (dihydrate). The pH of solutions was determined with a Beckman model G pH meter. Correction of pH of the nigrosin solutions was made with citric acid.

Since pH of the stain had been emphasized by Emik and Sidwell (1947) and Mayer *et al.* (1947), the pH of the stain solution used by Blom was determined. It was found that a 5 percent aqueous solution of eosin had a pH of 6.10 and the 10 percent nigrosin solution had a pH of 8.25. To determine the effect of variations in pH, mixed stain solutions of eosin and nigrosin in citrate buffer were prepared with pH values of 6.4, 7.2, and 8.7. The mean percentage of dead sperm from 10 different samples stained with each of the above was, respectively, 30.8, 29.5, and 29.6, with the very slight differences being non-significant statistically. The color contrast and appearance of the smear was best in the pH 8.7 stain in the majority of the comparisons. It is possible that a higher percentage of dead sperm would have been found if the mixed stain had been reduced to pH 6.1 since Mayer *et al.* (1951) found that all ram sperm stained below pH 6.4 and above pH 8.5. Obviously, however, this is not true of bull sperm in citrate buffer.

Other significant differences between the stains used by Blom (1950) and others were the method of mixing and the osmotic pressure of stain solutions. Since sperm are killed quickly in water or seriously hypotonic solutions, mixing the sperm thoroughly with aqueous eosin may have caused the killing and staining of cells which were alive when mixing started. To test this possibility 30 samples of semen

were each stained (1) with 5 percent aqueous eosin and 10 percent aqueous nigrosin separately according to Blom (1950), (2) with 2 percent eosin and 10 percent nigrosin solutions in 3 percent sodium citrate (dihydrate) separately, (3) with 1 percent eosin and 5 percent nigrosin solutions in 3 percent sodium citrate (dihydrate) mixed, and (4) with 0.8 percent eosin and 2 percent fast green FCF in 3 percent sodium citrate (dihydrate) mixed according to Mayer *et al.* (1947). The eosin was decreased to 1 percent when mixed with nigrosin

TABLE 1. A COMPARISON OF THREE STAINING MIXTURES CONTAINING EOSIN AND NIGROSIN AND ONE OF EOSIN AND FAST GREEN USED FOR DIFFERENTIAL STAINING OF LIVE AND DEAD BOVINE SPERMATOZOA

Stain and Method	Dead sperm (30 samples)		Half stained dead sperm (11 samples)	
	Mean	S.D.[1]	Mean	S.D.
	%	%	%	%
(1) 5% eosin, 10% nigrosin, aqueous, mixed separately	60.3	18.58	28.3	17.62
(2) 2% eosin, 10% nigrosin, in citrate buffer, mixed separately	44.0	22.16	33.8	25.60
(3) 1% eosin and 5% nigrosin mixed in citrate buffer before staining	43.7	19.63	39.2	20.39
(4) 0.8% eosin and 2% fast green FCF mixed in citrate buffer before staining	44.7	24.03	24.3	11.82

[1] S. D. is the standard deviation.

before staining because it was found that the latter gave satisfactory results, whereas 0.5 percent eosin did not give sufficient color contrast. A summary of these comparisons is given in table 1.

The mean percentage of dead sperm found in treatment 1 was significantly higher than that found with the other treatments, and there were not statistically significant differences between any of the other treatments. Since the mixing methods of 1 and 2 were the same, the high results with Blom's procedure were undoubtedly due to use of aqueous eosin instead of eosin dissolved in isotonic citrate buffer. When the eosin and nigrosin were mixed before staining the sperm, as in treatment 3, the results were practically the same as with separate eosin staining in treatment 2. These treatments also

gave essentially the same results as Mayer's fast green-eosin stain used in treatment 4.

In all of the live-dead differential stains of bovine spermatozoa it has been noted that some of the sperm do not take a noticeable stain in the anterior portion of the head which is covered by the galea capitis. The reason for these half-stained sperm has not been determined. One possibility would be that they are sperm which had been dead only a very short time and therefore have more resistance to distribution of the dye than do long-dead sperm. Since the high proportion of dead sperm in treatment 1 has been attributed to killing during the mixing process, a higher percentage of half-stained dead sperm should have been found to support this theory. The percentage of half-stained dead sperm from each of 11 semen samples treated with the four stains and methods outlined above was determined. As shown in table 1, there were not important differences between the stains in this respect, hence it is unlikely that the half-staining is a result of very recent death of the sperm.

Blom's method emphasized the importance of size of droplets of semen, eosin, and nigrosin solutions, using twice as much nigrosin as eosin. This proportion would have given his final mixture a concentration of 1.7 percent eosin and 6.7 percent nigrosin but this would not have occurred until the dead sperm had already been stained in 5 percent aqueous eosin. It is logical to suppose that the size of semen droplet used was emphasized primarily for the purpose of achieving suitable sperm concentration on the slide. However, the effect of varying amounts of semen upon the live-dead differential stain has not been reported. Therefore, a comparison was made of the percentage of dead sperm to be found by mixing varying proportions of semen and dye. Four semen samples were used, each as pure and diluted semen. The results of this comparison are shown in table 2. It is apparent that there were not significant differences among the average percentages of dead sperm due to proportion of semen and dye. Slides with the most suitable concentration of sperm for easy examination resulted from the use of 1 part of pure semen and 10 to 15 parts of staining solution. With diluted semen the best slides resulted from the 1:1 or the 1:2 combinations.

Comparisons in the last experiment in addition to previous observations, suggested that the same semen will have fewer dead sperm when mixed with egg yolk prior to staining than when used in the pure state. Since the eosin-nigrosin stain can be used very satisfactorily with yolk-diluted semen, it was important to know the relative value

of live-dead counts made with pure and diluted semen. The possibility of nigrosin concentration affecting the percentage of stained sperm in diluted and undiluted semen was also examined. Mixed stain solutions containing 2.5, 5.0, and 10.0 percent nigrosin were used to stain each of six different semen samples immediately before and after dilution with yolk-citrate diluter. The percentages of dead sperm were converted to angles and the data analyzed for statistical significance using the analysis of variance as proposed by Snedecor (1940). Differences due to stain concentration were not found significant. The diluted semen averaged 17.7 percent dead sperm which was highly significantly less than the undiluted semen with 20.7 percent dead sperm average.

TABLE 2. COMPARISON OF VARYING PROPORTIONS OF SEMEN AND STAIN SOLUTION IN THE DIFFERENTIAL LIVE-DEAD STAINING OF BOVINE SPERMATOZOA WITH EOSIN-NIGROSIN STAIN

Proportion of semen to stain solution	1:1	1:2	1:5	1:10	1:15	1:20
Av. percentage dead sperm (4 samples)	34.0	34.3	32.3	34.0	33.8	34.8

Discussion

Of various factors affecting the application of an eosin-nigrosin staining mixture for the differentiation of live and dead bull spermatozoa, the isotonicity of the staining medium is of prime importance. The method originally proposed by Blom (1950) was not comparable to other tested methods because some of the bull spermatozoa were killed in the aqueous eosin. Correcting the osmotic pressure by dissolving less eosin in isotonic buffer resulted in values comparable to those from other methods in common use. Varying the pH from 6.4 to 8.7, varying the semen to stain proportion from 1:1 to 1:20, and varying the concentration of nigrosin from 2.5 to 10.0 percent did not change significantly the percentage of dead sperm found. The pH results are in contrast to those with ram sperm reported by Mayer *et al.* (1951). This difference is probably due to the superior buffering capacity of bull semen although there may also be species differences in pH resistance of the cells.

Since the nigrosin concentration did not affect the live-dead count, and it is used only as a background stain, its concentration should be such as to produce a good background with a minimum of stain.

More than 5 percent in the mixed stain was not necessary, and there was some difficulty in spreading and instantaneous drying of smears made with 10 percent nigrosin. The smears made with 2.5 and 5 percent nigrosin were equally satisfactory, although slightly better color contrast was secured with the 5 percent solution. The background in both was violet with the stained sperm showing bright red. Protoplasmic droplets, bacteria, and live sperm appear unstained, shaded, or brilliant white depending upon the thickness of the smear. The background is completely homogenous.

It is recommended that the staining mixture be prepared by mixing 1 gm. of eosin B and 5 gm. of nigrosin in 100 ml. of sterilized 3 percent sodium citrate (dihydrate). This mixture has remained stable for more than one year without refrigeration. However, it should be refrigerated to prevent growth of bacteria, but warmed to room temperature before it is used for staining sperm.

Summary

The application of a staining mixture containing eosin and nigrosin for the differential staining of live and dead bovine spermatozoa has been investigated. This staining mixture gave results comparable to those with an eosin-fast green mixture when it was mixed in isotonic sodium citrate solution. Mixing in distilled water resulted in abnormally high percentages of dead sperm. Variations in pH from 6.4 to 8.5 and varying the proportion of semen to stain from 1:1 to 1:20 did not affect the percentage of dead sperm. The concentration of dyes found most suitable was 1 percent eosin B and 5 percent nigrosin, although variations in these amounts from 50 to 200 percent did not alter the accuracy of the live-dead differential count. The nigrosin background stain mixes satisfactorily with egg yolk diluter, but fewer stained sperm are found from diluted than from pure semen. The nigrosin stain gives a very homogenous background and highlights clearly the morphological characteristics of the sperm.

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THE RELATIONSHIP OF THE INTERVAL BETWEEN INSEMINATIONS TO BOVINE FERTILITY[3]

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IN the breeding of dairy cattle, cows frequently return to service at intervals different than the usual 21 day estrous cycle. The opinion has developed that the chances for conception in cows returning at irregular intervals are greatly reduced. In some instances this has led to the restriction of breeding to those cows which return to service within a few days of the 21 day average.

Chapman and Casida (1937) reported that 40 percent of 690 clinically normal cows showed estrous cycles less than or greater than 17 to 24 days. According to the report of Asdell *et al.* (1949) on estrous cycle length in 906 cows from artificial breeding records in New York, 16 percent of all cows showed cycles shorter or longer than an 18 to 24 day period. Ellenberger and Lohmann (1946) reported that 30 percent of 274 estrous cycles observed in cows occurred at intervals less than or greater than 17 to 25 days. The data of these investigators showed that the percentage conception of the cows in the 17 to 25 day cycle group averaged 55 percent as compared to 40 percent for those cows with shorter cycles and 48 percent for those with longer cycles. The statistical significance of these differences was not indicated.

These reports indicate that withholding service from cows showing irregular estrous cycles is apt to involve more cows than generally realized. If such cows are more difficult to settle, as suggested by Ellenberger and Lohmann (1946), then breeders and breeding units probably are increasing their breeding efficiency by refusing service to those cows. However, the fact that some of the cows with irregular cycles do conceive suggests that the reduction in number of cows settled may be more of a sacrifice than is justified in order to maintain a high breeding efficiency record.

The following study was made to determine the relationship of the interval between inseminations to the fertility of cows that were being bred after a previous unsuccessful service in artificial breeding.

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[3] The authors are indebted to the management of the Southern Illinois Breeding Association, especially Mr. F. G. Stevenson, for the cooperation given in collecting the records and to Mr. F. P. Shannon for his help in assembling the data for this paper.

Methods

The service records of the Southern Illinois Breeding Association were used to compile data on the intervals between services on a portion of the cows bred by that unit from February 1948 through January 1949. These tabulations included intervals between first and second services and intervals between second and third services only. The

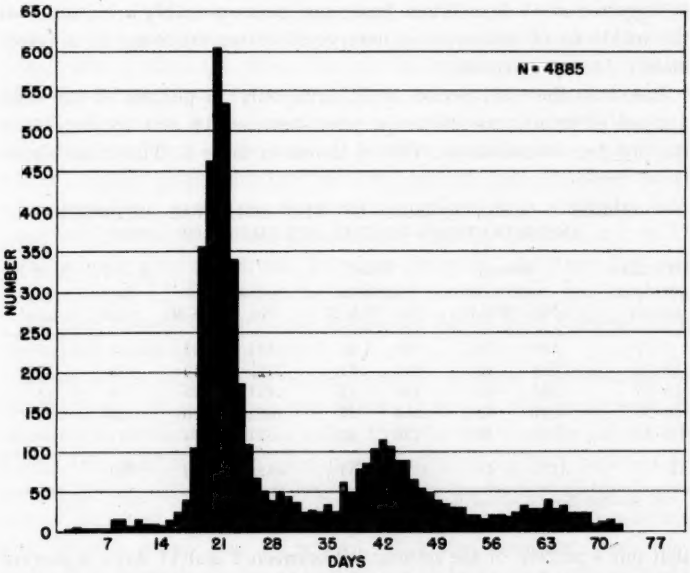

Figure 1. Histogram of the intervals at which cows were returned for artificial insemination after a previous unsuccessful service.

intervals between further services were not included because of the danger of too many cows being considered poor breeding risks and not being returned for artificial service, even though no limit or extra charge was made by the breeding unit for more than three services. Intervals exceeding 72 days were not included because of the possibilities of abortions or other irregularities being involved. The percentage non-returns were based on the number of cows failing to return to service within 180 days. Statistical analyses of the data were made using the chi square method as described by Snedecor (1946).

Results and Discussion

Data were accumulated on 4885 separate cases showing the interval between two consecutive artificial inseminations of cows, including 3173 between first and second services and 1712 between second and third services. The distribution of these intervals in days is shown in figure 1. This histogram shows the greatest number occurred on and around 21 days. Another peak in numbers is shown around 42 days, and a third is suggested at 63 days. These latter two peaks probably are a result of the incidence of quiescent or unreported estrus recurring at approximately 21-day intervals.

Based on the total period of 72 days, only 56 percent of the total number of returns to service occurred between 18 and 25 days after the previous insemination. This is shown in table 1. This table shows

TABLE 1. RELATIONSHIP OF THE INTERVAL BETWEEN INSEMINATIONS TO THE FERTILITY OF COWS

Days since previous service	Second services		Third services		Total services		% of 72 day total	% of 35 day total
	No.	%N.R.[1]	No.	%N.R.	No.	%N.R.		
2–17	116	29	61	43	177	34	4	5
18–25	1763	46	962	54	2725	49	56	82
26–35	262	40	149	53	411	45	8	13
36–50	687	46	364	57	1051	50	21	—
51–72	345	52	176	60	521	54	11	—
All	3173	46	1712	55	4885	49	100	—

[1] N. R.—180 day non-returns to service.

that but 4 percent of the returns fell between 2 and 17 days, 8 percent occurred within 26–35 days, 21 percent fell in the 36–50 day group and 11 percent occurred between 51 and 72 days.

When the number of animals returning to service in 35 days or less are considered, which would eliminate the cows having recurring estrous cycles unless they were shorter than 18 days, 82 percent fell between 18 and 25 days, 5 percent occurred at intervals of 17 days or less, and 13 percent fell in the 26 to 35 day group. The percentage distribution of the intervals between inseminations in this study was quite similar to the findings of Chapman and Casida (1937) for the distribution of estrous cycles when the data were grouped on the same interval basis. Also, the results are not greatly different than the findings of Ellenberger and Lohmann (1946) and Asdell *et al.* (1949) when considered on a comparable interval basis.

Table 1 also shows the average percent 180 day non-returns to service for the 5 interval groupings, broken down to the separate services and showing the total services. The percent non-returns to second services are all lower than shown for the third services. This is likely a result of the sale of animals and the failure of cows to be returned to artificial service for other reasons. Data reported by VanDemark and Salisbury (1950) based on calves born from natural breeding and by Barrett *et al.* (1948) based on pregnancy diagnosis in artificial breeding show that the percentages of actual conceptions go down with each additional service after the first. Though the percentage non-returns to third services in this study may not have been as representative of the actual pregnancies as the non-returns to second services were, the data indicating the effect of the interval between inseminations on fertility follow a similar pattern for both services. In both cases the distribution by intervals was similar on a percentage basis. Also in both the indicated fertility was lowest for those cows returning to service at 2 to 17 days after the previous service. Based on the totals, the group that was inseminated 2–17 days after the previous insemination was the only group that showed a non-return percentage significantly different than the overall mean of 49 percent.

Based on the distribution of the intervals between inseminations in this study and the percentage non-returns to service, the effectiveness of breeding or eliminating the so called irregular cows can be calculated. Eighty-two percent of the total cows in this study that returned to service 35 days or less after failing to conceive on the first or the second service, returned between 18 and 25 days, inclusively. The non-return rate for this group was 49 percent. Had the remaining cows that returned at intervals shorter or longer than 18 to 25 days been withheld from service because they were considered poor breeding risks, only 40 out of every 100 cows would have been settled at that one estrus. However, those cows that returned at intervals shorter or longer than 18 to 25 days were bred, and an additional 7 or 8 cows were settled at that one particular estrus. Thus there was an increase of approximately 20 percent in the total number of cows settled when all cows were bred regardless of the interval at which they returned as compared with the number settled had a practice of breeding only those cows returning 18 to 25 days after the previous insemination been followed. Though breeding all cows regardless of when they returned lowered slightly the over-all breeding efficiency, more cows were settled within a given period of time after they were submitted to service. Following a practice of breeding cows regardless of estrous cycle length would still require close

observation and proper treatment for the problem cow such as the nymphomaniac. Unfortunately, it was not possible to show in this study whether continued irregularity in any one particular cow had any effect on the fertility of that particular cow. However, the percentage of cows not returning to service even though bred after intervals that commonly would be considered irregular is strong evidence that the interval between inseminations does not affect conception greatly, unless the interval is of short duration.

Summary

Data showing the interval between two consecutive artificial inseminations (4885 cases) to cows were collected along with the fertility data for each interval as determined by 180 day non-returns to service. The distribution of these intervals showed definite peaks in numbers at 21 and 42 days. Based on the total recorded intervals up to and including those of 72 days length, 56 percent fell in the 18 to 25 day class, while 82 percent fell in this class when the totals for the first 35 days only were considered. The fertility levels based on non-returns to service after cows were inseminated 2–17, 18–25, 36–50, and 51–72 days after the previous insemination were 34, 49, 45, 50, and 54 percent, respectively. Only the fertility of those cows that returned for insemination at intervals of 2 to 17 days differed significantly from the mean fertility level. An increase of approximately 20 percent in the number of cows settled at any one estrus is indicated for a practice of breeding all cows regardless of the interval at which they return from a previous insemination as compared to a policy of breeding only those cows returning between 18 and 25 days after the previous service.

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THE INTERVAL BETWEEN THE TIME OF OVULATION AND ATTACHMENT OF THE BOVINE EMBRYO

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THE time at which the chorio-allantoic membrane becomes attached to the uterine wall may be a critical stage in the development of the bovine embryo for it is during this period that a transition takes place in the method by which the embryo receives its nourishment. In the early stages of development the embryo receives sufficient nourishment from the uterine milk which is absorbed by the chorionic sac; but as the embryo grows, its needs become greater and a more permanent and direct source of nourishment is established. During early placentation the embryonic tissue comes in intimate contact with the maternal tissue. If the proper response for attachment is not made by either tissue concerned, the embryo will soon stop its development.

Very little information has been published relative to the exact time, place, and manner of attachment of the embryonic membranes of the bovine embryo to the caruncles of the uterus. The limited information available gives a wide variation in time when the attachment process is supposed to occur. Most of this information has been obtained during studies upon some other phase of embryonic development.

Winters, Green and Comstock (1942) reported that "attachment of the embryo to the uterine wall takes place during the eleventh to twelfth days" after fertilization.

Hammond (1927) stated that "at the end of the first month of pregnancy the foetal membranes have not yet become attached . . ., but attachment to the cotyledon by projections from the foetal membranes occur before the end of the second month".

Kingman (1948) reports that "the fiftieth to the ninetieth day of gestation is the period of implantation and included those factors that make possible the first steps in establishing direct communication between the mother and the fetus. By the ninetieth day of gestation a fragile union has been established in the regions surrounding the embryo, but toward the apices the separation remains complete".

Hallman (1925) made observations upon the development of the fetal placenta from cows 3 to 5 months pregnant. He was concerned chiefly with pathological conditions of the placenta.

Hatch (1941) obtained weights of gravid uteruses from a series of

40 cows ranging from 21 to 260 days of pregnancy. The histology of the changes of the endometrium from these pregnant uteruses was described but no mention of attachment of the embryonic membrane was made except that no membranes were attached to the caruncles in the non-pregnant horn of a 3 week pregnancy.

Dukes (1943) indicates that attachment of the bovine embryo takes place after the thirtieth day.

Materials and Methods

Twenty-four cows and heifers of mixed beef breeding were used. They were observed three times daily for signs of estrus and were bred twice during estrus. After the second breeding, the ovaries of each animal were checked by palpation *per rectum* every 4 hours until ovulation occurred.

The animals were killed in the college meats laboratory at various intervals from 676 to 927 hours after ovulation. Three of the animals were not pregnant but had apparently normal corpora lutea, and three had resorbing embryos; therefore, data were collected from the remaining 18 animals.

The embryonic membranes with the embryos intact were recovered by dissection. Measurements were made of the length of the membrane that contained the fluid (allantoic sac), and the length of the chorion in both the gravid and non-gravid horns. The number of placental plates were counted and the membranes, fluids, and embryos were weighed to the nearest 0.1 gm. Before removing the embryo from its chorionic sac, discs of filter paper about one-half inch in diameter were cut and laid over four or five of the placental plates. These discs adhered readily to the damp chorionic membrane, thus aiding in their removal and in subsequent fixation and dehydration. A crown rump measurement was made of the embryos and they were weighed to the nearest 0.01 gm.

Five or six of the caruncles immediately surrounding the embryo, and in most of the animals one or two caruncles from the non-gravid horn, were removed and studied histologically for structures which indicated attachment.

Results

Before attachment of the bovine embryo takes place there is considerable preparation between the choric-allantoic membrane and the uterus of the mother. Normal caruncles from a non-pregnant cow have a layer of epithelial cells covering their surface (figure 1A). The first response of the caruncles to the embryonic membrane is the loss of this

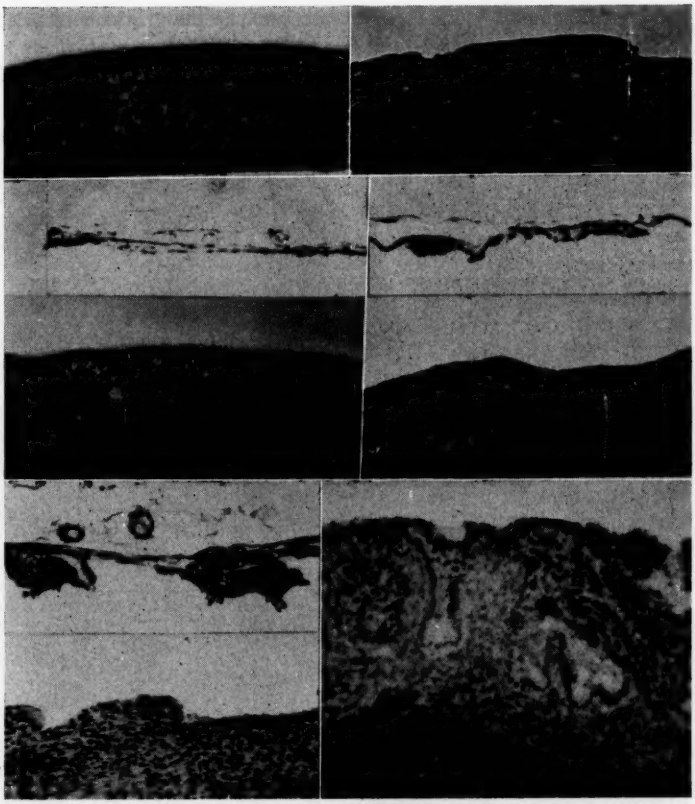

Figure 1. A. Section of a caruncle from the uterus of a non-pregnant cow showing surface epithelium overlying the submucosa. X100.
B. Section of a caruncle from the uterus of the non-gravid horn of a 713-hour pregnant cow. The submucosa has lost portions of the surface epithelium. X100.
C. Section of caruncle and of the choric-allantoic membrane from a 713-hour pregnant cow. Neither the embryonic nor the maternal tissue show preparation for attachment at this stage other than loss of surface epithelium. X100.
D. Section of caruncle and of the choric-allantoic membrane from a 754-hour pregnant cow. This shows the first indication of the formation of placental plates by the trophoblastic cells on the chorion and the undulating response of the caruncle. X100.
E. Section of caruncle and of the choric-allantoic membrane from an 800-hour pregnant cow. The trophoblastic cells have formed the anlage of the chorionic villi. X100.
F. Section of caruncle penetrated by the chorionic villi from a 927-hour pregnant cow. X50.

surface epithelium (figure 1B). This occurred in the gravid horn prior to the time of the youngest embryo recovered.

The attachment is a gradual and continuous process and since most

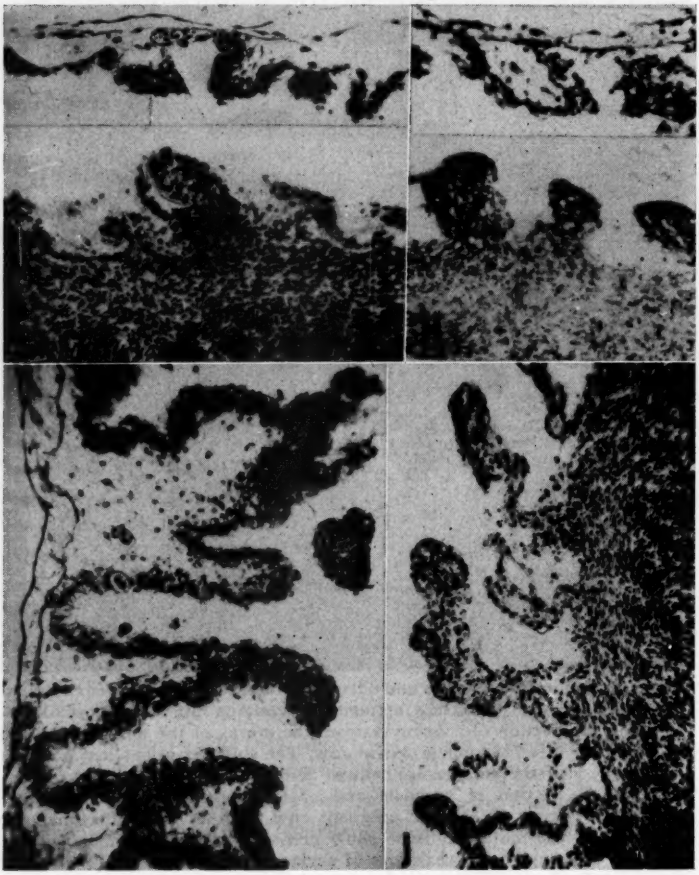

Figure 2. G. Section of caruncle and of the choric-allantoic membrane from 850-hour pregnant cow showing the first intimate attachment between embryonic and maternal tissue.

H. Same as above.

I. Section through the fetal cotyledon from a 40-day embryo. Note development of villi with numerous giant cells. X100.

J. Section of maternal cotyledon from uterus of 40-day pregnant cow. Cotyledon separated from section in C above. X100.

of these animals were killed with only a few hours difference in the age of the embryos, it was difficult to tell in many cases a noticeable histological change in the caruncles. In order to facilitate the description of the attachment changes, four stages or phases are arbitrarily set up. In each case the most advanced caruncles were selected for observation and these were obtained from the region immediately surrounding the embryo. In the first stage the caruncles had changed from a smooth-round surface (figure 1C) to an undulated surface. This occurred

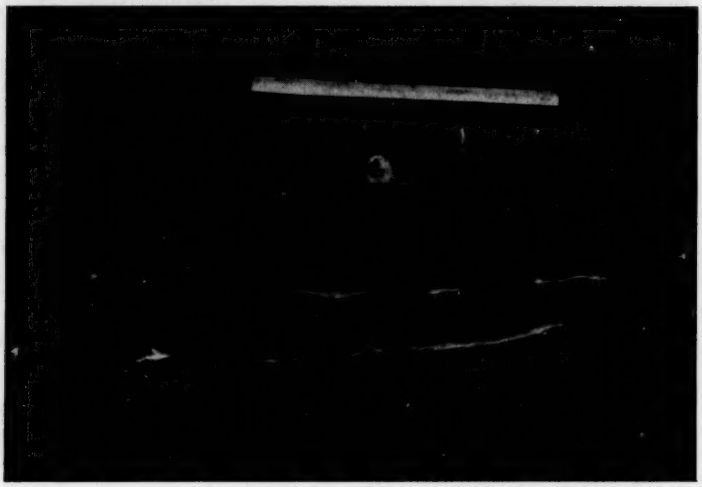

Figure 3. Embryonic membranes with embryo intact from 754-hour pregnant cow. Note amount of undilated portion of chorionic vesicle at this stage.

simultaneously with the proliferation of cones of trophoblastic cells, forming placental plates on the chorionic membrane over the caruncular areas (figure 1D). There were 8 to 12 of these placental plates on the chorionic membranes at the latter part of this stage, and they could be seen macroscopically by proper illumination. Each of these is the anlage of the fetal cotyledon. Their growth and development produce the undulated surface of the caruncles, and they later form the villi that penetrate the submucosa of the caruncle. At this time the allantoic sac does not extend to the end of the chorionic vesicle, thus leaving an undilated portion in each horn (figure 3). This stage of the development was reached by the 754-hour embryo (31 days). There was no union between the embryo and the mother during this first stage.

In the second stage of the attachment process the trophoblastic cones increased in length and formed individual villi. As these villi grew, they penetrated or eroded their way into the submucosa of the caruncle, and a very slight penetration or erosion was detected microscopically (figure 1E). There were from 16 to 22 placental plates present on the surface of the chorionic membrane. By this time the allantoic sac was

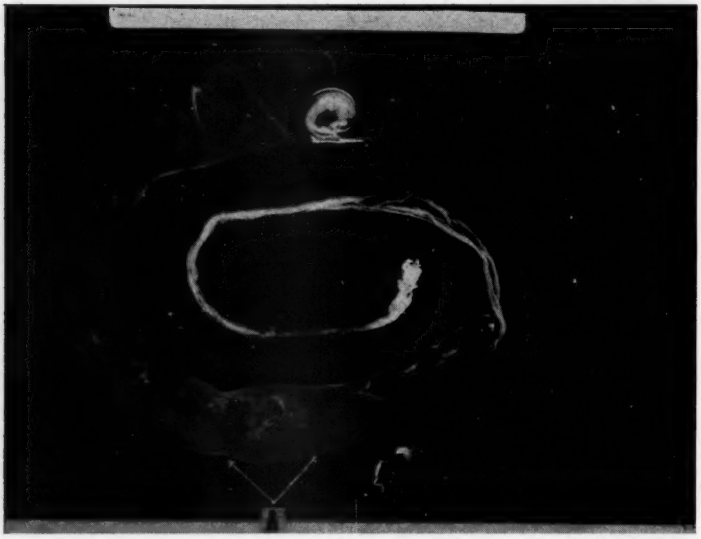

Figure 4. Embryonic membranes with embryo intact from an 850-hour pregnancy. Note a few small placental plates near embryo. The chorionic sac is completely dilated in the gravid horn of the uterus. (1A) Portion of the chorio-allantoic membrane located in the body of the uterus.

completely dilated in the gravid horn but there was still an undilated portion in the non-gravid horn (figure 4). There was only a very fragile attachment between the maternal and chorionic tissue at this stage, which is characteristic of the 800-hour embryo (33 days).

In the third stage the finger-like villi with a mesodermal core had penetrated or eroded deep enough into the caruncle to establish intimate union between the chorionic tissue and caruncles, and branches were produced which grew laterally as well as deeper into the submucosa (figure 2 G&H). When the embryonic membranes were removed, a part of the chorionic villi remained within the maternal cotyledon. There were from 17 to 25 placental plates present on the

surface of the chorionic membrane and the largest one measured 5.0 mm. in diameter. It was during this stage that the first placental plates appeared on the surface of the chorionic membrane in the body of the uterus. In the two previous stages they were limited to the region of the gravid horn. This stage of development was reached by the 850-hour embryo (35 days).

After the 850-hour period or during the fourth stage there were only two animals killed. They were sacrificed at 881 hours and 927 hours after ovulation.

At this stage the villi had grown deeper into the caruncle and formed a network of lateral branches. Even though microscopic examination of the caruncular tissue showed considerable attachment between the embryonic and uterine tissue, the two tissues separated readily when the embryonic membranes were removed from the uterus. Most of the chorionic villi remained within the maternal cotyledon when removing the embryo and membranes from the uterus. The trophoblastic cells of the villi had larger nuclei than those of the caruncular cells and stain darker with hematoxylin, thus giving contrast to the two tissues (figure 1F). The 881-hour and 927-hour embryos had 25 and 33 placental plates present on the surface of the chorionic membrane, respectively. The largest placental plate measured 7.4 mm. in diameter but as yet none could be seen in the non-gravid horn at this age. The allantoic sac was completely extended in the gravid horn, and that portion of the embryonic membrane which lies in the body of the uterus could be easily recognized by the slight constrictions about midway of the chorionic membrane (figure 4A).

A more advanced stage of the attachment of the caruncle and chorionic membrane (cotyledon) was obtained from an embryo whose crown rump measurement indicated its age to be 40 days (figure 2 I & J).

Discussion

According to Trimberger (1948) individual animals vary in time of ovulation after estrus; therefore, it was deemed necessary to determine as nearly as possible the time of ovulation so a more accurate estimate of the age of the embryo could be made. To make this determination, each animal was checked for the time of ovulation by palpation of the ovaries *per rectum,* through the intestinal wall. After the end of estrus, each animal was checked at 4-hour intervals to determine the time of ovulation. By using the half-way mark between the time an animal was found to have ovulated and the preceding time when she was checked,

the exact time of ovulation would not be more than 2 hours off from the estimated time.

While checking these cows, two follicles ruptured during palpation. In both of these cases the animals failed to become pregnant from that breeding; however, they became pregnant at the following breeding. It is assumed that either the ova were released before they were mature enough to be fertilized, or that through the handling of the ovary the ovarian-bursa was not in a position to catch the ova.

The time of 38 ovulations were determined. The right ovary was more active, producing 26 (68.42 percent) of the ovulations. When considering only the 18 ovulations that resulted in pregnancies, from which the data on the embryos were collected, a somewhat higher occurrence of ovulation (77.77 percent) was found in the right ovary. In every case the embryo was in the uterine horn on the side which the corpus luteum occurred in the ovary.

No record was made of the number of placental plates on the surface of the chorionic membrane until the 765-hour embryo; however, they first appeared in the 720-hour embryo as evidenced by histological changes in the caruncle.

The placental plates on the chorionic membrane were not equally distributed on the ventral and dorsal sides. About two-thirds of the placental plates appeared on the ventral side. This may indicate that the pressure from the embryonic membranes on the caruncles in the ventral portion of the uterus stimulates a proliferation of cones of trophoblastic cells on the chorion in that portion sooner than in areas where there is less pressure.

Tanabe and Casida (1949) found that cows of low fertility but with normal reproductive tracts had a satisfactory percentage of pregnancies (66.1 percent) when killed on the third day after breeding, but of those cows killed 34 days after breeding, only 23.1 percent were pregnant. The embryonic death rate was 65.1 percent.

Three animals killed during this investigation were found to have resorbing embryos and three others were not pregnant. It is possible that the three that were not pregnant at the time of slaughter had been pregnant earlier but death of the embryo may have occurred soon after fertilization of the ova and complete resorption had already taken place. The reproductive tracts of these six animals appeared normal in every respect, and the corpora lutea were normal in size and appeared to be functional.

There is no substantial evidence to indicate that the 741-hour embryo was dead when the mother was sacrificed but the measurements give

TABLE 1. AGE, LENGTH AND WEIGHT MEASUREMENTS OF EMBRYOS AND EMBRYONIC MEMBRANES

Age	Embryo				Length of Embryonic Membranes				Weight of Embryonic Membranes and embryo intact	Placental plates
	Length		Weight			Undilated Chorionic Sac				
	Before dehydration	After dehydration	Before dehydration	After dehydration	Allantoic sac	Non-gravid horn	Gravid horn	Total		
hrs.	mm.	mm.	gm.	gm.	cm.	cm.	cm.	cm.	gms.	no.
676	11.0	7.9	0.15	0.11	44.9	27.5	20.2	92.6	22.2	none
713	12.8	9.7	0.26	0.14	44.3	28.8	19.2	92.3	39.3	"
720	13.5	10.5	0.44	0.15	—	—	—	—	—	present
741	12.5	9.3	0.25	0.12	27.6	21.6	17.5	66.7	20.0	"
754	14.3	10.3	0.48	0.22	38.4	39.2	29.6	107.2	47.1	"
765	14.7	11.6	0.36	0.21	48.5	41.0	filled	89.5	48.2	14
777	15.7	11.3	0.57	0.22	51.1	38.3	"	89.4	52.9	9
781	16.5	12.4	0.55	0.29	45.0	39.7	"	84.7	76.5	17
783	—	12.8	0.45	0.28	46.1	34.2	"	80.3	57.7	14
797	14.4	12.2	0.41	0.21	50.5	29.4	"	79.9	50.8	16
801	17.9	13.1	0.56	0.26	63.1	25.4	"	88.5	61.7	22
805	18.0	14.6	0.55	0.34	50.0	43.5	"	93.5	74.7	present
813	17.3	13.7	0.53	0.30	52.4	24.6	"	77.0	63.7	24
822	17.1	13.5	0.46	0.27	60.8	33.1	"	93.9	65.3	23
838	16.4	13.6	0.49	0.29	49.5	25.2	"	74.7	64.5	17
850	19.4	15.2	0.72	0.43	61.2	28.3	"	89.5	81.4	19
881	19.4	14.7	0.68	0.37	71.3	filled	"	71.3	78.5	25
927	21.0	18.7	1.09	0.71	81.1	"	"	81.1	136.8	33

reason to think it might have already died. A small amount of variation may be seen in the age-size relationship, but the measurements of the embryonic membranes of the 741-hour embryo were smaller than those of any other (table 1).

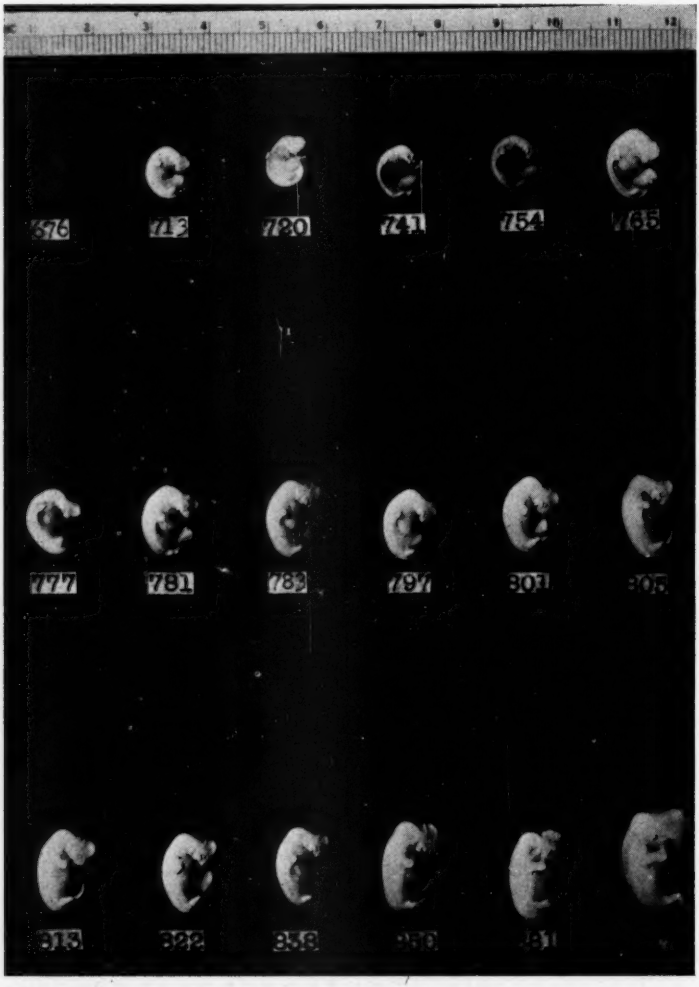

Figure 5. Series of 18 embryos ranging in age from 676 hours to 927 hours from time of ovulation.

The growth and development of the embryo is very rapid. The length of the 927-hour embryo was more than twice that of the 676-hour embryo and the weight was more than six times as great (table 1). Figure 5 shows the comparative size of the embryos. The length and weight of the embryos made as soon as the embryos were recovered from the uterus as well as those made after dehydration in 75 percent alcohol are given in table 1.

It is thought that the length and weight measurements of the embryos made after dehydration are more accurate than those taken of the embryos when first recovered; therefore, the measurements made after dehydration were used in the correlation studies (table 2). The correlations were made on 17 animals, omitting animal No. 3 since some of the data on this animal were not obtained; however, in the regression coefficient of age on length the data from all the animals were used.

The correlations (Snedecor 1946) were all highly significant except those involving the total length of the chorionic membranes, and they showed a slightly negative correlation. One would expect a very low or negative correlation involving the length of the chorionic membrane since there was no increase in the length from 676 hours to 927 hours (table 1). The highest correlation was 0.97 which was found between weight of embryo and total weight of embryonic membranes and embryo; however, this would be expected since the weight of the embryo was a portion of the latter. A correlation of 0.96 was found between age and length of embryo; therefore, r^2 or 91.45 percent of variance in age is accounted for by the variation in length, leaving $1-r^2$ or 8.55 percent as residual variation which is due to causes other than length. This residual variation may be due to difference in curvature of the embryos, and the error of measurement may also account for part of the variation. It is possible that the variation in age, size, breeding, and former care of dams caused some of the variation. Within the period of this study, the age of the bovine embryo can be fairly accurately estimated by its length.

Summary and Conclusions

1. Data for this experiment were taken from 18 heifers and cows, which were killed at intervals from 676 to 927 hours after ovulation.
2. The first response of the caruncles in the uterus for attachment is the loss of the surface epithelium.
3. Attachment is not a sudden process but is gradual and continuous over a period of several weeks. The first points of attachment are

TABLE 2. CORRELATION COEFFICIENTS BETWEEN THE VARIABLES STUDIED AND THE MEAN AND STANDARD DEVIATION OF EACH

	Means	Standard deviation	Correlation Coefficients (r)				
			Embryo length	Embryo weight	Length of allantoic sac	Length of embryonic membranes	Weight of embryo, membranes and fluid
Embryo Age	795.5 hrs.	14.6 hrs.	.96	.89	.82	.34	.89
Embryo Length	12.6 mm.	0.19 mm	...	.94	.82	.22	.95
Weight of Embryo	0.28 gm.	0.03 gm.	...	...	.81	.26	.97
Length of Allantoic Sac	52.1 cm.	3.03 cm.	...	...	...	.08	.82
Length of Embryonic Membranes	85.4 cm.	2.41 cm.	...	...	...	...	.07
Weight of Embryo, Membranes and Fluid	61.2 gm.	6.4 gm.	...	...	...	...	...

immediately around the embryo and this is where the first placental plates can be seen on the chorionic membrane.

4. The first placental plates appeared on the surface of the chorionic membrane immediately surrounding the embryo in the 720-hour (30 days) embryo, and they first appeared on the chorionic membrane in the body of the uterus in the 850-hour (35 days and 10 hours) embryo; but none were found in the non-gravid horn in the 927-hour (38 days and 15 hours) embryo. In the early phases of attachment about two-thirds of the placental plates appeared on the ventral side of the chorionic membrane.
5. The allantoic sac completely filled the chorionic sac in the gravid horn of the 765-hour (31 days and 21 hours) embryo, and in the 881-hour (36 days and 17 hours) embryo the allantoic sac completely filled the chorionic sac in the non-gravid horn.
6. At 754 hours or 31 days after ovulation the caruncles immediately surrounding the embryo have changed from a smooth-rounded surface to an undulated surface.
7. At 800 hours or 33 days after ovulation there is a very fragile attachment between the maternal and chorionic tissue at three or four of the caruncles immediately surrounding the embryo.
8. At 850 hours or during the thirty-fifth day after ovulation the attachment has become firm enough that the embryo is undoubtedly receiving a portion of its nourishment through the cotyledons.
9. The right ovary was more active in production of ova than the left ovary, (68 percent).

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VITAMIN E DEFICIENCY IN THE LAMB[1]

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VITAMIN E deficiency is characterized grossly by locomotor disturbances and general muscular dystrophy (Zenker's degeneration). Degeneration of skeletal and cardiac muscle has been experimentally produced and described in mice (Pappenheimer 1942), rats (Pappenheimer 1939), guinea pigs and rabbits (Goettsch and Pappenheimer 1931) and encephalomalacia in chicks (Pappenhemer *et al.* 1939 and Jungherr 1949).

Metzger and Hogan (1927) observed an identical condition in lambs. Under the title of "Stiff-Lambs" the authors described the symptoms and degenerative changes of the skeletal and heart muscle. The degenerative changes in the musculature were reported as non infectious and non inflammatory in nature. Since then many workers in this country and abroad have described a similar condition among lambs.

Willman *et al.* (1934) experimentally produced "Stiff-Lambs" from ewes kept on a ration consisting mainly of cull beans and alfalfa hay. From this experimental work the authors recognized the nutritional nature of the disease.

Morgulis *et al.* (1936), Shimotori *et al.* (1940), Mackenzie *et al.* (1940) and Willman *et al.* (1940) reported that wheat germ oil, wheat germ meal, wheat bran and α-tocopherol would protect guinea pigs, rabbits and lambs from nutritional muscular dystrophy.

Willman *et al.* (1945, 1946) prevented "Stiff-Lamb" disease either by administration of mixed tocopherols to the ewes before and to their lambs after parturition or by administration of d, 1-α tocopherol acetate to the lambs immediately after birth. The same authors successfully treated affected lambs by subcutaneous injection of a disodium salt of d, 1-α tocopherol phosphoric acid in an aqueous solution. Whiting *et al.* (1949), using the "Stiff-Lamb" producing ration of Willman (1934)

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compared the tocopherol levels of blood plasma from ewes and lambs, and also the colostrum and milk tocopherol levels from the ewes with a group of normal controls. The results indicated a reduction from 15 to 48 percent in the tocopherol levels of the blood plasma, milk and colostrum in the ewes and lambs on the "Stiff-Lamb" producing ration.

In view of these findings it was believed that the nutritional muscular dystrophy described as "Stiff-Lambs" or "White Muscle" disease was due to Vitamin E deficiency. A purified diet in liquid form was successfully used by Luecke *et al.* (1950) and Drapper and Johnson (1951) to produce riboflavin and thiamine deficiencies in young suckling lambs. It seemed plausible that by using a similar purified diet low in tocopherols the role of this vitamin in animal nutrition and particularly its relationship to nutritional muscular dystrophy of lambs could be studied and possibly elucidated.

Experimental

Beginning with the fall, 1950, 32 lambs 3–4 days old were used for this experiment. Lambs of both sexes, of the mutton and fine wool type, were obtained from the Experiment Station flock. All lambs received colostrum before being removed from the ewes. The care of the animals, the composition and the method of preparation of the "synthetic" milk were the same as described by Luecke *et al.* (1950). A few modifications were made; the lambs were changed from one pen to another every day instead of every other day, 10 percent glucose was substituted for lactose and the lambs were fed four times a day instead of five. Seven out of the 32 lambs died early in the experiment due to causes not related to Vitamin E deficiency and were diagnosed as overeating (3 lambs), volvulus (1 lamb), coccidiosis (1 lamb) and pneumonia (2 lambs). The work reported herein consisted of two trials. The source of fat in the purified liquid diet in the first trial was commercial lard purchased locally.

In the second trial molecular distilled lard lower in vitamin E was used as the source of fat in the synthetic diet. The lard contained less than 5 micrograms of tocopherols per gram and was obtained from Distillation Products, Inc.[4]

Results and Discussion

The first trial consisted of 5 control and 10 experimental animals. During the experiment it was realized that the amount of vitamin E in

[4] Distillation Products, Inc., Rochester 13, New York.

commercial lard was apparently sufficient to greatly delay the deficiency symptoms. Madsen *et al.* (1935) and others produced the muscular dystrophy characteristic of vitamin E deficiency in laboratory animals by supplementing the diet with cod liver oil. To check the possibility of inducing the same muscular dystrophy with cod liver oil in lambs, two control and three deficient animals previously on commercial lard diet for 40 days were treated daily for 25 days with 3 ml. of fresh cod liver oil. There was no significant difference between the treated and non-treated lambs in regard to the time required to produce the symptoms or the severity of the muscular dystrophy. Trial No. 2 consisted of

TABLE 1. EFFECT OF COMMERCIAL AND MOLECULAR DISTILLED LARD AND COD LIVER OIL ON TIME REQUIRED TO PRODUCE SYMPTOMS OF VITAMIN E DEFICIENCY

Trial	No. of lambs	Diet	Lard Used	Cod Liver Oil Therapy	Days to produce deficiency symptoms
	5	Positive control	Commercial	—	No symptoms
1	10	E low	Commercial	—	30–80
	2	Positive control	Commercial	3 ml. daily	No symptoms
	3	E low	Commercial	3 ml. daily	62–74
	4	Positive control	Molecular distilled	—	No symptoms
2	6	E deficient	Molecular distilled	—	14–50

4 control and 6 lambs on experimental diets. The source of fat in the diet of this group was molecular distilled lard, very low in tocopherols, and especially suitable for experimental work with vitamin E. There was a very significant difference in the time necessary to produce the deficiency depending on whether distilled or commercial lard was used. However, in each case the time required to produce deficiency symptoms varied widely in different lambs. There seemed to be no breed difference noted in this respect. The summary of the two trials is presented in table 1.

Growth

It was understood from the work of Willman *et al.* (1945, 1946) and from the reports on "Stiff-Lambs" from the field, that the appetite

of the affected lambs was not greatly depressed, at least, in the first stages of deficiency. It was thus felt that the growth rate would not be a major criterion of deficiency. Feeding the lambs four times a day from the bottle was found to be rather inadequate in obtaining optimal growth rate (Kean *et al.* 1949, Luecke *et al.* 1950). Despite this limitation in feeding in this experiment, the control and the experimental lambs on both commercial and distilled lard diet grew normally, made moderate daily gains and stayed in good health and condition for a period of about 28 and 14 days respectively. After this time the lambs not supplemented with α-tocopherol started to show characteristic symptoms of pneumonia. The affected lambs were treated with 100,000 units of procaine penicillin injected intra-muscularly in the neck region every other day. This therapy had to be continued until the end of the experiment in order to keep the animals alive. On autopsy 9 out of 16 vitamin E deficient lambs showed muscular dystrophy and localized unilateral or bilateral pneumonia. From 8 controls only one lamb showed pneumonia. The other deficient lambs with no complications of pneumonia despite the existing symptoms of muscular dystrophy retained a very good appetite and remained in good condition until they were sacrificed or died due to heart failure. The control lambs on the same diets supplemented with 100 mg. of α-tocopherol, administered orally every other day made daily gains which very well compare with daily consumption of dry matter reported by Luecke *et al.* (1950).

Blood

All of the lambs were bled every week for determination of hemoglobin, total white blood cell count and differentials. Every other week additional blood was drawn for analysis of tocopherols. The average hemoglobin value of all lambs at the beginning of the experiment was 13.1 gm. per 100 ml, of blood. The range was 11.1 to 15.9. The average hemoglobin value of the control just before the termination of the experiment was 13.2 gm./100 ml. of blood, indicating that the control lambs maintained about normal hemoglobin level throughout the experiment. In every vitamin E deficient lamb there was a gradual drop of hemoglobin level. The average hemoglobin value was 11.6 gm./100 ml. of blood, excluding two lambs which developed anemia at the end of the experiment and showed values of 5.1 and 5.6 gm. of hemoglobin per 100 ml. of blood. No significant pattern was exhibited by the total leucocyte or differential count. However, in every case the total white blood cell count was significantly increased if deficiency was complicated with pneumonia.

The total tocopherol content of blood plasma was determined by the hydrogenation method of Quaife and Biehler (1945). The initial or presumably normal level of tocopherols in blood plasma was determined on 12 lambs. These determinations were carried out on blood drawn from 0–7 days after the lambs had been placed on the experimental diet. The values ranged from 0.070 to 0.244 mg. of total tocopherol per 100 ml. of blood with average value of 0.149. This great variation in the tocopherol content of blood among one week old lambs would suggest differences in storage of this vitamin in the new born animal. The results of the blood analysis for total tocopherol during the experiment are shown in table 2. In every case the values represent at least 2 analyses for each of the 19 lambs. The control lambs on the commercial lard diet supplemented with 100 mg. of α-tocopherol every other day definitely increased the total tocopherol level of plasma throughout the experiment while the control lambs on the molecular distilled lard treated similarly showed a slight decrease and were unable to maintain the presumably normal tocopherol level.

Deficient lambs on the commercial lard diet showed a gradual and consistent drop of the total tocopherol content of blood plasma over the 70 day experimental period. In the case of the diet containing molecular distilled lard a much more pronounced drop in the total tocopherol content of the plasma occurred in 20 to 35 days. All lambs in this group died or were sacrificed within 50 days.

Administration of cod liver oil for 25 days to positive control and deficient lambs on the commercial lard diet significantly lowered the tocopherol content of the blood plasma.

It was noticed that the characteristic symptoms of deficiency were invariably associated with very low tocopherol content of the blood. The critical values are somewhere below 0.081 mg. of total tocopherol per 100 ml. of blood.

Symptoms and pathology

Symptoms and gross pathology of the so called "Stiff-Lamb" disease were adequately described by Willman *et al.* (1934), Lee *et al.* (1935) and others. Our observations of the symptoms and pathological changes experimentally produced in the lamb on vitamin E deficient diet compare with those of the above mentioned authors. The first noticeable symptoms appeared in about 14 to 28 days after being placed on the vitamin E deficient diet. The lambs were reluctant to walk and to cross small obstacles. The negotiation of small obstacles was accomplished with

TABLE 2. TOTAL TOCOPHEROL CONTENT OF BLOOD PLASMA OF EXPERIMENTAL LAMBS

Trial	No. of lambs	Diet	Lard Used	Cod Liver Oil Therapy	Days on Experiment	
					30–45	60–70
					mg/100 ml	mg/100 ml
	4	Positive control	Commercial	—	0.485 0.212 0.266 0.266 .... 0.307[a]	0.281 killed cod liver oil cod liver oil 0.281
1	8	E low	Commercial	—	0.075 0.095 0.097 0.141 0.147 0.141 0.106 0.141 .... 0.118[a]	killed 0.069 0.119 killed cod liver oil 0.109 killed cod liver oil .... 0.099[a]
	2	Positive control	Commercial	5 ml. daily	0.266 0.266 .... 0.266[a]	0.169 0.156 .... 0.162[a]
	2	E low	Commercial	5 ml. daily	0.147 0.141 .... 0.144[a]	0.072 0.072 .... 0.072[a]
					20–35	50–60
	3	Positive control	Molecular distilled	—	0.150 0.131 0.109 .... 0.130[a]	0.148 0.109 .... 0.128[a]
2	4	E deficient	Molecular distilled	—	0.040 0.054 0.065 0.109 .... 0.067[a]	

[a] Average

difficulty or by falling. Later on, a definite stiffness, especially of the hind legs was noticeable followed by inability to get up. However, when assisted to a standing position the animals were not able to walk but assumed a characteristic arched back stance (figure 1). After standing for a short time the animals would lose equilibrium and fall. In the later stages of deficiency the lambs were paralyzed in both hind and front legs and were unable to move. This was the typical sequence of events during the experiment. In a few cases, the lambs on vitamin E

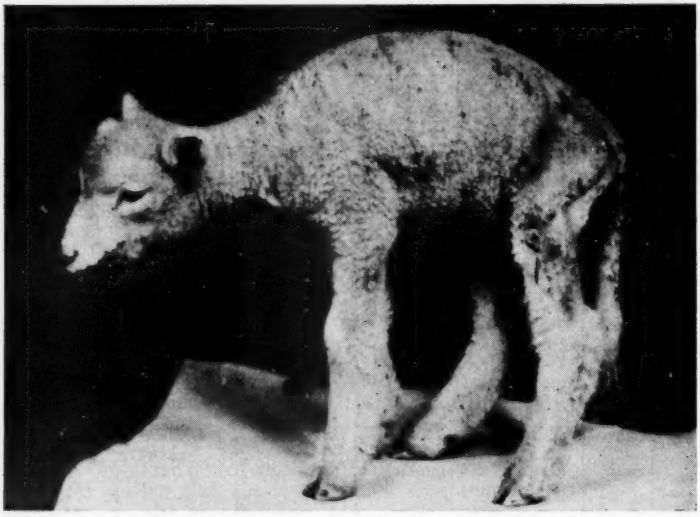

Figure 1. Lamb fed Vitamin E-free diet, showing typical symptoms of "Stiff-Lamb Disease".

deficient diet showed a mild stiffness but did not develop the above mentioned sequence of symptoms characteristic of chronic deficiency. These lambs died suddenly without showing any severe stiffness or paralysis. Post mortem examination of these lambs clearly indicated heart failure due to extensive lesions in the heart as a cause of death. Gross pathological studies of the vitamin E deficient lambs revealed degeneration of skeletal and cardiac muscle ranging from very mild to severe dystrophy depending on the length of time the particular lamb was on the deficient diet. It was observed that the muscles of both hind and fore legs were affected earliest and showed much more severe degeneration than the muscles of the shoulder, rump, loin and the

neck. In very severe cases, practically all of the musculature was affected including the diaphragm, intercostal muscles and the tongue. The lesions in the skeletal muscles appeared on the surface of the muscle as whitish areas or streaks usually affecting only part of the muscle. On cross section the whitish or grayish areas again indicated that not all of the muscle fibers and bundles were affected. Careful examinations of the carcasses showed that both sides of the body were about equally affected.

The most striking feature of the deficient lambs was the characteristic lesions in the heart, which were invariably present within the right ventricle. In only two cases the lesions were present in both ventricles and atria, including the aorta and appeared in the epicardium. Again depending on the length of time the animals were on the deficient diet, the lesions usually appeared in the form of round patches, ranged in size from pin point up to 10 mm. in diameter and occurred singly, in groups or were very diffuse and affected most of the ventricle (figure 2). The hearts in general were flabby and the amount of fluid in the pericardial sac was greatly increased. Those lambs which died suddenly showed very severe and extensive heart lesions. The liver and kidney of the lambs with secondary pneumonia usually showed fatty degeneration, and the adrenals were markedly enlarged and hemorrhagic. Other organs, including stomach, intestinal tract, spleen, urinary bladder and thyroid did not show pathological changes.

Two lambs from the second trial which showed advanced symptoms of deficiency characterized by inability to get up were treated with α-tocopherol diluted in fresh corn oil. The initial dose was 500 mg. of α-tocopherol, followed by 100 mg. every other day. The solution was administered orally by means of a syringe with a rubber hose in place of a needle. A definite response to the therapy was noticed in three days. On the fourth and fifth day the animals were able to get up and to move to some extent. Later on during the therapy the animals were able to move freely and did not show any symptoms of deficiency. The lambs were sacrificed on the 12th and 20th day of the treatment. In both cases the degeneration of the skeletal and cardiac muscle was still visible. It was observed, however, that especially in the case of the second lamb (20 days of therapy) the muscle degeneration seemed to be less marked. The heart lesions were grayish in color, less whitish and ischemic than in progressive degeneration. Regeneration of both skeletal and cardiac muscle was undoubtedly in progress. Sections were taken for histopathological studies.

While this experimental work was in progress, many cases of the

so-called "Stiff-Lamb" disease were reported by farmers from Michigan. A number of cases were brought to the laboratory for necropsy and

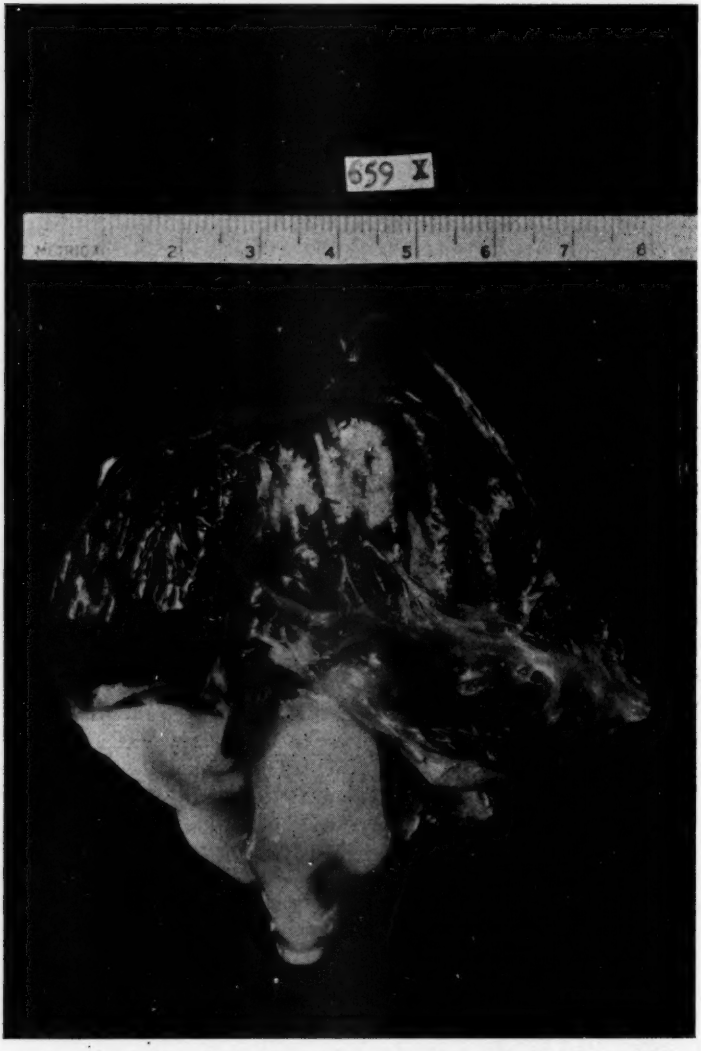

Figure 2. Lesions in the heart from a lamb on Vitamin E-free diet.

the authors have had an ample opportunity to study and compare the pathology of both field and experimental cases at the same time. Furthermore, the incidence of the "Stiff-Lambs" in the flock at Michigan State College permitted the authors to observe the symptoms of the disease in the field. The sequence of the symptoms, the symptoms themselves and the degenerative lesions in the skeletal and cardiac muscle were identical with those produced experimentally in the lamb by using the vitamin E deficient diet. Again the heart lesions invariably found in the right ventricle and secondary pneumonia were the characteristic features of nutritional muscular dystrophy occurring under the field conditions.

Summary

Nutritional muscular dystrophy in the lamb was produced by using a liquid, purified vitamin E deficient diet. The symptoms of vitamin E deficiency were characterized by low total tocopherol level in blood, disturbance in locomotion, stiffness, paralysis, susceptibility to pneumonia and sudden death.

Post mortem examination showed Zenker's degeneration of the skeletal and cardiac muscle.

The lesions in the heart were invariably in the right ventricle.

Administration of α-tocopherol alleviated the symptoms in 3–5 days to a great extent.

A complete regeneration of the muscle is no doubt a process of longer duration. Symptoms and degenerative changes of the so called "Stiff-Lambs" from the field appeared to be identical in every respect with the nutritional muscular dystrophy produced in the lamb on vitamin E deficient diet.

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VITAMIN B_{12} VS. VITAMIN B_{12b} FOR COBALT DEFICIENT SHEEP

BERL A. KOCH and SEDGWICK E. SMITH
Cornell University[1]

SMITH *et al.* (1951) have shown that vitamin B_{12} injected in sufficient quantity will alleviate the symptoms of cobalt deficiency in lambs. This paper summarizes further evidence confirming this and also compares the effects of injected vitamin B_{12} with one of its derivatives; namely, B_{12b}. Evidence at hand indicates that vitamin B_{12b} and B_{12a} are identical and that both differ from B_{12} in having a hydroxy group in place of a cyano group.

Methods

The 18 lambs used in this study were selected from the original group of 25 used in a previous experiment (Smith *et al.*, 1951). All lambs which had responded to a previous treatment were again reduced to a state of serious cobalt deficiency. The methods of handling and the rations fed were the same as in the previous experiment (Smith *et al.*, 1951) except for the hay. The hay used in this study was from a different source and was lower in cobalt (0.03 ppm.) than that used previously. Lambs were assigned to treatment groups by selective randomization. The lambs were first divided into groups of similar previous treatment. From these groups, lambs were randomized into three treatment groups. The three treatment groups used in this study were as follows: One group of six lambs received subcutaneous injections of vitamin $B_{12}b$[2] during the first five weeks (the extent of our available supply) and vitamin B_{12}[3] during the last seven weeks of the study. A second group of six lambs received subcutaneous injections of vitamin B_{12}[4] throughout the twelve week study period. A third group of six lambs was used as both a negative and a positive control group. During the first three weeks they were carried as a negative control group and received no treatment. At that point, oral cobalt therapy was initiated and they were carried as a positive control group for twelve weeks.

[1] Department of Animal Husbandry.
[2] Courtesy of Lederle Laboratories.
[3] Merck and Co., Inc.
[4] Lederle during the first two weeks—Merck thereafter.

The vitamin B_{12b} and vitamin B_{12} were in a water solution which contained 20 mcg. of vitamin per ml. of solution. Both vitamin B_{12b} and vitamin B_{12} were injected subcutaneously twice per week at the rate of 125 mcg. per week during the first two weeks. Thereafter injections were made once per week at the rate of 100 mcg. per week. The control group received cobalt orally as $CoCl_2 \cdot 6H_2O$ in water solution at the rate of one mg. per day. All six lambs were treated twice weekly until they showed an appetite response. Thereafter each lamb received 7 mg. of cobalt orally once per week.

As the lambs in the various groups responded to treatment, as shown by an increase in appetite and body weight, the ration offered was

TABLE 1. WEIGHT RESPONSES OF COBALT-DEFICIENT LAMBS WHEN INJECTED WITH VITAMIN B_{12b} OR VITAMIN B_{12}

Treatment	No. lambs	Average Body Weight			Total vitamin per lamb
		Pretreatment week	5th week	12th week	
		lbs.	lbs.	lbs.	mcg.
Vitamin B_{12b}[1]	6	57	72	88	1217
Vitamin B_{12}	6	56	70	86	1283
Cobalt (oral)	6	57	74	88	0

[1] For 5 weeks and then B_{12} for 7 weeks.

increased. This increase was rather rapid until each lamb received a maximum of 420 grams of shelled corn, 80 grams of skim milk powder, and 500 grams of chopped low-cobalt hay.

Results and Discussion

A positive or negative response to treatment was determined by an increase or decrease in concentrate consumption (corn and milk powder) and body weight. Hemoglobin values were determined biweekly but they were not used as a primary measure of response to treatment. The hemoglobin responses were rather erratic and of a much lower magnitude than appetite and weight responses in all groups. This slowness of hemoglobin response in cobalt-deficient lambs treated with cobalt has been noted by others (Filmer, 1933; Filmer and Underwood, 1937; Becker and Smith, 1951).

Response to treatment as measured by body weight increase is summarized in table 1. Weights are shown for the fifth week and the twelfth week of treatment. Weights for the fifth week are shown in

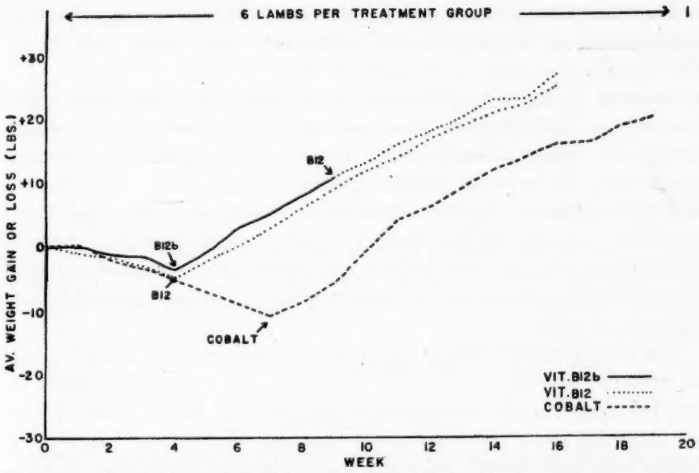

Figure 1. Average body weight changes of the three treatment groups during a sixteen week period.

order that vitamin B_{12b} and vitamin B_{12} therapy might be compared with each other and with oral cobalt therapy. Figure 1 shows the weight changes of the three treatment groups graphically during a sixteen week period. Note that all three treatment groups showed a definite decline in body weight prior to the time treatment was started. The animals in the control group continued to lose weight until after they were fed cobalt salts whereupon they showed a quick response.

Response to treatment as measured by appetite is summarized in table 2. The lambs in all three groups showed a very definite appetite response. Those lambs that were injected with vitamin B_{12b} or vitamin B_{12} appeared to respond a little more rapidly during the first

TABLE 2. APPETITE RESPONSES OF COBALT-DEFICIENT LAMBS WHEN INJECTED WITH VITAMIN B_{12b} OR VITAMIN B_{12}

		Average Daily Concentrate Intake					
Treatment	No. lambs	Pretreatment week	1st week	2nd week	3rd week	5th week	12th week
		gms.	gms.	gms.	gms.	gms.	gms.
Vitamin B_{12b}[1]	6	68	187	370	430	492	500
Vitamin B_{12}	6	91	176	337	399	488	500
Cobalt (oral)	6	62	89	259	410	500	500

[1] For 5 weeks and then B_{12} for 7 weeks.

two weeks than those fed cobalt. However, all three groups reached maximum feed consumption at about the same time (fourth to fifth week).

Changes in body weight of the three treatment groups are summarized in figure 1. Note that during the four week pretreatment period the lambs of each group were losing weight. Those lambs which were to serve as positive controls (cobalt fed) were carried for three weeks as negative controls. It should be noted that they continued to lose weight throughout the negative control period. When cobalt therapy was initiated the control lambs showed a quick and consistent increase in body weight which is characteristic of cobalt deficient animals.

The two groups of lambs that received injections of vitamin B_{12b} or vitamin B_{12} during the first five weeks of the study showed a rapid response as measured by both appetite and weight gains. These weight gains were analyzed using analysis of variance (Snedecor, 1946) with total weight gains and also individual regressions of gain on time as units of measure. The difference between the weight gains of these two groups of lambs was not statistically significant as measured by either method. This observation is in accord with those made by other investigators. Stokstad *et al.* (1950) reported that vitamin B_{12} and vitamin B_{12b} have similar activity for both chicks and *L. leichmannii.* Kaczka *et al.* (1951) reported that the biological activities of vitamin B_{12a} and vitamin B_{12} are similar in assays using *L. lactis, L. leichmannii,* chicks, rats and humans. Evidence at hand indicates that vitamin B_{12a} and vitamin B_{12b} are identical (Kaczka *et al.,* 1950, 1951, and Hendlin and Soars, 1951) and both differ from vitamin B_{12} in that the cyano group of the latter is replaced by a hydroxy group (Brink *et al.,* 1950). When the vitamin B_{12b} injections were replaced at the end of five weeks with injections of vitamin B_{12} there was no apparent change in the weekly rate of gain of the lambs.

Table 1 summarizes the total weight gains of the three treatment groups during the 12 week treatment period. The average daily gain for all three groups of approximately 0.35 pounds is a very satisfactory gain for fattening lambs. The total gains made by each of the three treatment groups were very similar. An analysis of variance (Snedecor, 1946) using either total weight gains or individual regressions of weight on time revealed no significant differences among them.

This study demonstrates again that vitamin B_{12}, when injected,

will alleviate the symptoms of cobalt deficiency in lambs and furthermore, that vitamin B_{12b} is as effective in this respect as vitamin B_{12}. The amount of cobalt in these vitamins is so small that the activity can not be due to cobalt *per se*. Although cobalt may have other metabolic functions in the ruminant body, its utilization in the production of vitamin B_{12} is certainly one of its more important functions.

Summary

It has been demonstrated that vitamin B_{12b} is as effective as vitamin B_{12} in curing a cobalt deficiency in lambs. Cobalt deficient lambs injected with 100–125 mcg. per week of vitamin B_{12} made excellent gains in weight over a period of 12 weeks, a length of time comparable with the usual commercial fattening period.

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ABSTRACTS OF PAPERS TO BE PRESENTED AT THE FORTY-THIRD ANNUAL MEETING OF THE AMERICAN SOCIETY OF ANIMAL PRODUCTION

The meetings are scheduled to be held at the Hotel Sherman in Chicago on November 23 and 24, 1951. Abstracts have been submitted for the following papers.

Breeding and Genetics Section

L. N. Hazel, *Chairman*

INFLUENCE OF AGE OF COW ON HER CONFORMATION SCORES. C. J. Brown, *University of Arkansas.*

Over a ten year period (1940–1950) seventy cows remained in the University of Arkansas beef herds until they were at least three and one-half years old. All cows were scored in both winter and summer and the average rating of two or more judges working independently was used to determine the score of a cow on a scoring date. Thirteen different judges scored the cattle. Only one scored all cows on all scoring dates. Some cows were scored as many as twenty times. For the purposes of analysis the cows were divided into age groups as follows: 3½–5 yrs., 5½–7 yrs., 7½–9 yrs., and 9½–11 yrs. Highly significant differences between the scores of these age groups as well as between the scores at different ages of scoring within the groups were noted. On the basis of the 726 scores of these seventy cows, it appears that there is a downward trend in the scores from calfhood until roughly the age of first lactation, after which the scores tend to increase up to about five and one-half years, which would roughly correspond to maturity. After maturity is reached the scores remain rather constant until changes associated with senility begin to cause a decline. The age at which a cow's score appeared to be most highly correlated with average lifetime score was three years (.81) and one and one-half years (.80).

RESULTS OF REBREEDING SOWS THREE DAYS AFTER FARROWING-EFFECT OF GONADOTROPIC HORMONE ON LITTER SIZE, BOAR ACCEPTANCE, FERTILITY, etc. J. H. Brown and Herbert G. Luther, *Arenel Farms and Chas. Pfizer & Co., Inc.*

Sows whose pigs were weaned at from 24 to 72 hours, and fed synthetic milk were rebred at three days after farrowing. Single breeding was practiced in all cases. 77% of the untreated group so bred accepted the boar (44 of a group of 57). The percentage would have been higher if breeding had been reattempted on the following day as ovulation seems related to length of the short nursing period, which in these animals ran from one to three days. In a similar group of sows treated with varying quantities of gonadotropic hormone all sows accepted service readily. Hormone levels were estimated on the basis of those used in large animals.

A STUDY OF SOME FACTORS INVOLVED IN PORK CARCASS EVALUATION. W. L. Brown, H. A. Stewart and T. N. Blumer, *North Carolina State College.*

One hundred fifty-six carcasses originating from different lines of breeding were processed over a four year period. Fifty-five objective and subjective measurements were taken on each carcass. From these measurements an index of carcass value was determined, based on information from previous research work. Carcass evaluation by this index is cumbersome and laborious. A shorter index was devised using the percentage yields of trimmed ham, shoulder, and loin on the shrunk live weight, multiplied by the relative prices of these wholesale cuts on a loin equivalent basis. Weekly Chicago wholesale prices for the five year period, 1946–1950, were used to determine the average price of each wholesale cut. The correlation between the short index and previous index was 0.83. A high positive correlation exists between average back fat thickness and weight per unit carcass length and between percentage lean cuts and the area of loin eye muscle between the third and fourth lumbar vertebrae. A high negative correlation was found between percentage of lean cuts and average back fat thickness. A simpler index for evaluation of pork carcasses is proposed.

ENDOCRINE ANALYSIS OF HOMOZYGOUS DWARF BEEF CATTLE. F. D. Carroll, P. W. Gregory and W. C. Rollins, *University of California.*

The homozygous dwarf beef cattle used in this study have phenotypic manifestations similar to those of cretins and experimentally induced thyroid-deficient animals reported in the literature. The thyrotropic hormone content of the pituitary glands from dwarf calves was compared to that found in normal calves. This was made by using the one-day-old chick cockerel test. It was found that four daily injections of a suspension of pituitary tissue from dwarf calves caused a slight increase in thyroid weight over control chicks. The injection of the same amount of pituitary tissue from normal calves caused a much greater increase in thyroid weight which was very significant statistically. The studies clearly indicate that there is a deficiency of thyrotropic hormone in these dwarfs. Further studies indicate that the dwarf pituitary is not lacking in the gonad stimulating and growth hormones.

THE EFFECT OF HETEROSIS ON THE BIRTH WEIGHT OF LAMBS. H. W. Carter and W. L. Henning, *Pennsylvania Agricultural Experiment Station.*

The birth weight of 1056 lambs was studied to determine the effect of heterosis on birth weight. These lambs represented five breeds of sheep and five crosses. The purebreds were; Merino, Dorset, Hampshire, Shropshire and Southdown. The crosses were; Dorset-Merino, Hampshire (Dorset-Merino), Southdown (Dorset-Merino), Shropshire [Hampshire (Dorset-Merino)], Southdown [Hampshire (Dorset-Merino)]. The birth weight of the cross-bred lambs were compared to the average birth weight of the lambs of the pure breeds involved. It was assumed that if there was no effect of heterosis, the birth weight of the lambs would fall midway between the mean birth weight of the breed of the parents involved, any increase above this average was considered as due to heterosis. Adjustments were made for differences due to years and number of individuals involved in any one year. Only the Southdown (Dorset-Merino) cross showed a significant increase. The Hampshire (Dorset-Merino) showed a decrease. The Shropshire [Hampshire (Dorset-Merino)] also showed a decrease but only 22 lambs were involved. These data show little if any effect of heterosis on birth weight. The difference between the weight of all purebred Hampshire lambs and that of all

purebred Southdown lambs in the control flock were 1.614 pounds. The difference between the Hampshire (Dorset-Merino) lambs and that of the Southdown (Dorset-Merino) lambs was .057 pound. This indicates that the ewe may have a greater influence on the birth weight of her offspring than her contribution of 50 percent of the genes of that offspring.

BEEF CATTLE IMPROVEMENT THROUGH SELECTION FOR INCREASED WEIGHTS OF SIX-MONTH-OLD CALVES IN A BRAHMAN-ANGUS POPULATION. W. M. Dawson, E. H. Vernon, A. L. Baker and E. J. Warwick, *U. S. Dept. of Agriculture*

Improvement of weaning weights in a Brahman-Angus population at Jeanerette, Louisiana, was studied by the Bureau of Animal Industry cooperating with the Louisiana Agricultural Experiment Station This report deals with comparable weights of six-month-old calves (446) obtained since 1945. The cows calved in January, February and March. Weights were made on grass with no supplements. Calf weights were markedly affected by years, sex of calf and age of dam. Each calf's weight was adjusted for differences in these factors. Sires' six-month weights had a correlation of —.06 with average six-month weights of their offspring. Dams' weights correlated 0.03 with weights of their offspring, within sire of offspring. Within sire of dam, the correlation between dams' and progenys' weights was 0.10. Heritability coefficients for six-months weight were 0, 5 and 15 percent respectively when calculated for the above comparisons. Both the average weight of the dams' previous calves at time of mating in 1948 and 1949 and weight of dam's best previous calf had correlations of 0.33 with weights of calves from those matings, when both were calculated within sires of 1948 and 1949 calves. The above indicate that progress in improvement of six-month weights is likely to be slow; a continuation of progeny testing is desirable; considerable attention should be paid to the progeny record of the dam; and evidence of dominant and epistatic relationships should be looked for.

SELECTION PRACTISED IN DEVELOPING INBRED LINES OF SWINE. G. E. Dickerson, C. T. Blunn, A. B. Chapman, R. M. Kottman, J. L. Krider, E. J. Warwick and J. A. Whatley, *Regional Swine Breeding Laboratory*.

Date studied included 4521 litters and 423 line-seasons from 38 lines developed by the Illinois, Indiana, Iowa, Missouri, Nebraska, Oklahoma and Wisconsin projects. Litter size and weight were adjusted to a gilt basis. Generation interval averaged 1.26 years for sires and 1.44 years for dams. Proportions of pigs weaned were .74 from 1-year-old and .26 from older sires, .60 from gilt and .40 from older dams. Proportions actually retained averaged .08 for boar pigs, .33 for gilt pigs, .63 for older boar and .48 for older sows. Selection differentials were similar for boar and gilt pigs selected in dam's litter size farrowed (.66 *vs.* .66 pigs) and weaned (1.40 *vs.* 1.20 pigs). Boars were selected more intensly than gilts for individual weight at weaning (6.2 *vs.* 2.5 pounds) and at 154 days (22 *vs.* 14 pounds), for litter average pig weight at weaning (4.2 *vs.* 2.4 pounds), for dams litter weight weaned (53 *vs.* 41 pounds), and for inbreeding of dam (—1.9 *vs.* —0.9 percent and of litter (—1.7 *vs.* —1.1 percent) "Deliberate" selection (exceeding that "automatic" under random selection) for dams performance was negligible for litter size, but averaged 3.0 and 1.5 pounds among boars and gilts for litter average weaning weights. Further selection of older sires was negative for own inbreeding (—1.2 percent) and for dams productivity, but slightly positive for own weight at weaning and 154 days (0.7 and 3.1 pounds). Annual selection of sows on own performance averaged .43 and .83 pigs for numbers farrowed and weaned, 25 pounds for total and 0.9 pounds for litter average weaning weight, 1.2 and 4.9

pounds in own weight at 56 and 154 days, and —0.3 and —0.9 for inbreeding of dam and individual. Discrepance between actual and expected improvement are attributed to associations between components of total performance more than to incomplete utilization of selection opportunity.

THE SUCKLING PERFORMANCE AND POST WEANING GAINS OF THE PROGENY OF TWO BEEF BULLS. W. C. Godley and H. A. Stewart, *North Carolina State College.*

In a study of performance of two Hereford bulls (bulls A and B) on grade Hereford cows, an attempt was made to determine whether or not there were differences among 242 offspring of the bulls in (1) weaning weight, (2) rate of gain of the steers in the feed lot, (3) slaughter grade of the steers, (4) total gain of the heifer calves from weaning weight until the end of their first pasture period and (5) weaning weight of 106 calves of the daughters of the bulls.

Calves sired by A were 14 pounds heavier at weaning than those sired by B. Sex, weight of cow and the age of cow had a significant effect on weaning weight of the calf.

No difference was found in rate of gain of steer progenies of the bulls. Weaning weight and intial feed lot weight affected rate of gain.

Steers sired by B were .11 of a slaughter grade higher than the steers sired by A. Final weight had a significant influence on slaughter grade. Gain in the feed lot had no effect on slaughter grade.

Daughters of A gained 19 pounds more from weaning until the end of their first pasture period than did daughters of B. Calves of the daughters of A averaged 37 pounds heavier at weaning than the calves of daughters of B.

Although B was considered superior in type, the performance of A was superior in all comparisons where differences occurred except slaughter grade of steers.

A PHENOTYPIC EXPRESSION OF HOMOZYGOUS DWARFISM IN BEEF CATTLE. P. W. Gregory, W. C. Rollins, P. S. Pattengale, and F. D. Carroll, *University of California.*

A study of head contours of over 60 dwarfs and several hundred normal animals of the Hereford, Angus, and Shorthorn breeds reveals that the outstanding characteristic of the specific type of dwarfisms studied is a brachycephalic head with a marked mid-forehead prominence present at birth and persisting throughout life. This type of contour is discontinuous with and does not intergrade into the type of contour of normal homozygotes. Accompanying this anomaly is a misshapen mandible in which there is marked malocclusion of the incisors with the dental pad. Incisors may extend forward to the dental pad from one-half to three and one-half centimeters. These characteristics are also symptoms of thyroid deficiency. Moreover, the stunted growth, heavy breathing, and extreme pot-belly of the dwarfs are manifestations of thyroid deficiency of hereditary or experimentally induced cretins. These morphological features are in agreement with physiological studies completed in our laboratory being reported in another paper which prove conclusively that dwarfs of this type possess a gross deficiency of the thyrotropic hormone.

MECHANICAL MEASUREMENT OF BACKFAT THICKNESS ON LIVE HOGS. L. N. Hazel and E. A. Kline, *Iowa State College.*

Backfat thickness can be measured readily on live hogs by making a shallow transverse incision through the skin of the back and pressing a blunt narrow ruler or metal bar through the soft backfat to the firm tissue underneath. The method

causes little discomfort to the pigs and a team of four men can take four measurements per pig per minute. The accuracy of the method was examined by taking live-hog measurements at four places along the backs on each of 96 hogs weighing about 220 pounds. The measurements on the live hogs were taken over the longissimus dorsi behind the shoulder, at the middle of the back and at the middle of the loin, and over the vertebra at the middle of the loin. Correlations between the averages of the four carcass measurements of backfat and percentage primal cuts, lean loin area, and lean ham area were —.35, —.23, and —.14 respectively. Those between the average of the four live-hog measurements of backfat and the same three measures of carcass leanness were —.45, —.31, and —.25, respectively. Measuring from skin to muscle gives a more accurate estimate of carcass leanness than measuring from skin to vertebra. While all of the live-hog measurements have low correlations with lean ham area, this perhaps may be improved by measuring fat covering on live hogs over the ham as well as over the longissimus dorsi.

GENETIC IMPROVEMENT IN A LINE OF HEREFORD CATTLE. Bradford Knapp, Jr., R. C. Church and A. E. Flower, *U. S. Dept. of Agriculture.*

Line 1 Hereford cattle at the United States Range Livestock Experiment Station at Miles City, Montana, has been bred and selected for economic performance for a period of 15 years. During that time most of the selection for performance was based on progeny tests by the feeding of steers from bulls of this line. The inbreeding has not increased as rapidly as is possible and at the present time averages about 16 percent. Relationship to one of the foundation sires was found to be much greater than to the other foundation sire. Heritability estimates were higher in this line than in the whole population reported by Knapp and Clark. Improvement in the line for rate of gain and weight at 15 months of age was found to be 0.16 pounds in daily gain and 66 pounds in weight at 15 months of age. It is assumed that these figures are conservative since they indicate only the improvement made due to selection of the sire and there has been some selection for weight in the females during this time. At the present time regression due to inbreeding has been rather low in the line. The cattle are criticized for their rather poor heads and somewhat rangy type but the line has not produced a single dwarf calf in the 15 years of breeding and is assumed to be dwarf free. It is expected that other lines will be developed that will perform better than this line but the authors believe that had not Line 1 performed well there would have been little incentive for other experiment station or purebred breeders to undertake the development of other lines based on economic performance.

HERITABILITY OF WEIGHTS OF BEEF STEERS BY MONTHS DURING THE FEEDING PERIOD. Bradford Knapp, Jr. and R. R. Woodward, *U. S. Dept. of Agriculture.*

Previous reports have indicated very high heritability estimates for weights of calves at 15 months of age. It has been the practice to feed for approximately a nine months feeding period but a previous report indicated that 168 days was sufficient to test for genetic growth ability. Heritability estimates of live weight at 28-day intervals during the feeding period where all animals were *ad libitum* fed, were calculated to determine the most economical length of feeding period to obtain genetic growth differentiation. Heritability is fairly high at birth and drops to 28 percent at weaning time. At the end of the first period heritability is still 28 percent but rises sharply from the end of the first period to the end of the 6th period. From the end of the sixth period to the end of the feeding period or ninth period there is little change in the heritability estimates with the estimates ranging

from 80 to 99 percent. The indications are that feeding periods as short as 112 days can be used to indicate genetic growth ability where *ad libitum* feeding is practiced. If these estimates present the true picture, it would seem that for bull testing under the sib testing program it would be possible to feed for 100 to 150 days with about the same degree of accuracy as the longer periods.

HERITABILITIES AND THE RELATIVE ACCURACIES OF INDIVIDUAL AND COMMITTEE SCORES FOR SOME TRAITS OF SHEEP. W. H. Kyle, *U. S. Dept. of Agriculture.*

The relative accuracies of individual and committee average scores were estimated by the magnitude of the correlation between half sibs within sex, breed and type of mating for all weanling lambs (1031 Rambouillet, 625 Targhee and 447 Columbia) scored in 1950. Each of two committees of three men working independently scored three traits on each lamb. Face covering, neck folds, type, staple length, condition and thigh wool (difference in fineness between wool on the side and thigh) were the traits scored. Committee average scores for the two groups of three traits were, on the average, 34% more accurate than individual scores and ranged from 12% to 73% more accurate than scores by the six individuals. Approximate heritabilities calculated from the pooled half sib correlations over all groups for the committee average scores were .36 for face covering, .26 for staple length, .25 for neck folds, .11 for condition, .08 for thigh wool and .06 for type. Separate heritability estimates for ram and ewe lambs indicate sex differences in heritabilities of neck folds and face covering. Side and thigh grades in spinning counts were placed on the wool of 1020 lambs (mostly Targhee and Columbia) by one scorer and gave approximate heritabilities of .26 and .38, respectively. Thigh wool scores calculated from differences in these grades gave a heritability estimate of .04. Because of their higher heritabilities, side and thigh wool grades may be more helpful additions to the selection index than a thigh wool score based on differences in fineness.

THE EFFECT OF GLUCOSE, EGG YOLK AND SEMINAL PLASMA ON THE COMPARATIVE METABOLIC ACTIVITIES OF EPIDIDYMAL AND EJACULATED SPERMATOZOA OF THE RAM. John F. Lasley and Dennis T. Mayer, *University of Missouri.*

A comparative study was made of the O_2 consumption of ejaculated and epididymal spermatozoa of the ram. Epididymal and ejaculated spermatozoa in isotonic phosphate buffer were compared. The former consumed but 68 percent as much O_2 as the latter during the first hour and 55 percent during the second hour despite the presence of a larger percentage of live and motile cells in the samples from the epididymis. Glucose, egg yolk and seminal plasma added to the phosphate buffer medium increased the O_2 consumption of epididymal spermatozoa markedly. The addition of egg yolk or seminal plasma to ejaculated spermatozoa did not result in a marked increase in O_2 consumption.

THE BOVINE PROTEIN-BOUND IODINE AS RELATED TO AGE, SEX AND BREED. J. F. Long, L. O. Gilmore, G. M. Curtis and D. C. Rife, *Ohio State University.*

Protein-bound iodine analyses were performed by the method of Connor *et al.* of the Department of Surgical Research (used as an index of thyroid activity) on blood samples from 116 dairy and beef cattle. The cattle were from the Ohio State Dairy and Beef Herd and the Veterinary Clinic. The animals were found to average

3.15 micrograms of iodine per 100 cc. of serum. (By the same analytical procedure, normal humans average 4.5 micrograms-%). When the data were arranged according to breed, they ranked as follows: Jersey 4.11, Guernsey 3.51, Brown Swiss 3.37, Ayrshire 3.19, Holstein 2.73 and beef breeds 2.19 micrograms-%. An analysis of variance performed by the Statistics Laboratory revealed significant or highly significant differences to exist between certain of the breeds. The Jersey breed for example differed significantly or highly significantly from all other breeds. The age of the animal was found to influence the level of protein-bound iodine in the blood. Calves of all breeds were highest (averaging 4.8 micrograms-%). There was a rather marked decline with age up to the age of 3–4 years (when the average was 3.1 micrograms-%) and then a very gradual decline (animals 7–8 years old averaged 2.6 micrograms-%). Results from a limited number of males did not reveal any sex differences.

CAUSES OF VARIATION IN GESTATION LENGTH IN SWINE. A. L. Musson. *Iowa State College.*

Analysis of 2517 periods of gestation from 1682 sows among one Danish Landrace and twelve Poland China inberd lines of swine was made by fitting constants for line of dam, inbreeding of dam, inbreeding of litter, age of dam, birth weight of litter, season of farrow (spring or fall) and type of mating (inbred or crossline). Genuine line differences were found to exist. Differences between lines accounted for thirteen percent of the variance. The line means ranged from 115.9 to 118.5 days, with the mean of the entire group at 117.03 days and a standard deviation of 1.97 days. Environmental effects included in the study were age of sow, birth weight of the litter, season of farrow and inbreeding of dam. These effects were found to be real but small. Weight of the litter at birth accounted for three percent of the variance and all together the five remaining effects accounted for three percent of the variance. The relation between birth weight of the litter and the length of gestation was negative. Litters weighing less than 10 pounds at birth were carried .9 of a day longer than the average, and litters weighing over forty pounds at birth were carried .7 of a day less than the average. Litters farrowed in the spring were carried .4 of a day longer than litters farrowed in the fall. Repeatability for length of gestation was .26. Heritability of the length of gestation was .21 as estimated from the resemblance between full sibs in 400 full sib groups.

SOME ASPECTS OF EGYPTIAN LIVE STOCK. Mohamed M. Oloufa, *Fouad I University, Giza, Egypt.*

Records of the Animal Breeding Department, College of Agriculture, from 1937 through 1949 were analyzed. The average gestation period in 115 Egyptian cattle and in 376 Egyptian buffaloes was 290.8 and 317.6 days respectively. On the average, males were carried longer than females in both cattle and buffaloes, though the difference lacked statistical significance. Records including 1141 services on 684 buffaloes and 1025 services on 529 cows showed a conception rate of 38.0 percent in the former and 35.1 percent in the latter. The difference in conception rate between buffaloes and cows was not statistically significant. The average birth weight for Egyptian cattle was 58.0 lbs. for males and 54.8 lbs. for females. For buffaloes, the average weight at birth was 85.0 and 84.1 lbs. for males and females respectively. The mean birth weight for Egyptian Ossimi sheep was 8.2 lbs. for males and 7.6 lbs. for females. In few cases studied, the body weight and the age of the dam were of no statistically significant effect on the birth weight of the Egyptian cattle, sheep and buffaloes.

HERITABILITY OF RACING CAPACITY IN THOROUGHBREDS. John Pirri, Jr. and Dewey G. Steele, *University of Kentucky.*

An estimate of the heritability of racing capacity in Thoroughbreds has been obtained by means of half-sib correlation applied to the earnings of 2352 male progeny of 199 stallions which had male progeny to race as three-year olds in 1946, 1947 and 1948. Heredity accounts for about 14 percent of the variance in racing performance as measured by earnings.

GENETIC AND ENVIRONMENTAL FACTORS AFFECTING YEARLING TRAITS OF NAVAJO AND NAVAJO CROSSBRED EWES. D. A. Price, G. M. Sidwell and J. O. Grandstaff, *Southwestern Range and Sheep Breeding Laboratory.*

The effects of age of dam, type of birth and rearing, year of birth, age of ewe in days and breeding groups were analyzed for 917 Navajo and Navajo crossbred yearling ewes, born in 1948, 1949 and 1950. The traits studied were yearling weight, type and condition scores, staple length, grease fleece weight and clean fleece weight. In general, type of birth and rearing had the greatest environmental influence on the traits studied. Grease fleece weight, clean fleece weight, yearling staple length and body weight were affected more by both the genetic and environmental factors studied than were those traits evaluated by scoring. Both body type and condition scores were influenced to a large degree by yearly differences. With the exception of staple length, large differences were found between years for the remaining traits. Yearling ewes from mature dams were heavier than ewes born of 2 year-old mothers. None of the remaining traits studied were significantly affected by age of dam differences. Differences between breeding groups were large. The pure Navajo ewes were less desirable in all traits except staple length when compared with Navajo crossbred ewes.

THE CHANGES IN THE TYPE RATINGS OF HOLSTEIN AND GUERNSEY COWS WHEN RATED BY THE SAME THREE JUDGES AT TWO CONSECUTIVE TIMES. R. W. Touchberry and K. R. Tabler, *University of Illinois and U. S. Dept. of Agriculture.*

Twenty Holstein and 16 Guernsey cows were classified for type independently by the same three official classifiers late in September of 1950 and in early July of 1951. At each time a separate rating was given for general appearance, dairy character, mammary system, feet and legs, rump, and body capacity in addition to the overall rating. Each of the above ratings were analyzed by the analysis of variance. Predominately the largest source of variation, explaining from 25 to 50 percent of the total variance, was the components of variance for cows within breeds. The next largest source of variation was the cow within breed by time interaction. This accounted for from 22 to 27 percent of the variation for general appearance, mammary system, dairy character and the overall rating. For feet and legs, rump, and body capacity this component was very small, explaining from 4 to 13 percent of the variance. The error components ranged from 13 to 36 percent of the total variance. The differences between classifiers were significant only for general appearance and body capacity and the components of variance for classifiers were very small in all cases. The main effects for time were significant in four cases, but accounted for only a small portion of the total variance. From this study it is concluded that cows very definitely change in classification from one time to another and this change is not in the same direction nor of the same magnitude for all cows.

INFLUENCE OF BREEDING AND ENERGY CONTENT OF THE RATION ON PORK CARCASSES. J. A. Whatley Jr., D. I. Gard, J. V. Whiteman, J. C. Hillier, *Oklahoma Agricultural Experiment Station.*

Twelve litters of four pigs each were used to determine the effect of restricted energy intake in the latter part of the fattening period on rate of gain, efficiency of gain and certain carcass characteristics. Seven different breeding groups were represented in the 48 pigs. All pigs were treated alike up to 140 pounds and then two pigs from each litter were self-fed a high energy ration to a slaughter weight of 225 pounds and two pigs of each litter were fed a low energy ration to the same weight. Restricting the energy intake by substituting ground hay for part of the corn in the ration reduced the rate of gain and increased the feed cost. It also resulted in a leaner carcass with a higher yield of lean cuts, but because of the lower dressing percentage the carcass value per 100 pounds of live hog was not increased. Breeding groups were significantly different in average daily gain and in many of the carcass items. Gilt carcasses were significantly leaner than barrow carcasses. Differences in many carcass characteristics were greater between breeding groups than between treatments or sexes.

PREDICTING WEIGHTS OF WHOLESALE CUTS OF BEEF FROM LIVE ANIMAL MEASUREMENTS. F. E. White and W. W. Green, *University of Maryland.*

Linear measurements, live weight, and slaughter grade as well as weights of wholesale cuts of the carcasses were secured from fifty, average-run, commercial steers of beef breeding purchased on the Baltimore market. The steers ranged in weight from 800 to 1445 pounds (average 1120±158 pounds) and in slaughter grade from choice to medium (old standard); the bulk being choice and good. Live weight was the best single measure for predicting the weight of the cut from the live animal (simple correlations of weight of animal and weight of cut ranged from 0.89 to 0.94). Slaughter grade was poorly correlated with weight of cut. These correlations ranged from 0.02 to 0.03 for all cuts except the round (0.27). Width and depth measurements were more useful for predicting the weight of cuts than were length measurements. Multiple correlations (R) of weight of cut with associated linear measurements plus live weight and slaughter grade were as follows: short loin, 0.93; sirloin butt, 0.95; trimmed loin, 0.96; rough loin, 0.97; round, 0.93; rib, 0.97; and cross-cut, 0.99. When using only width and depth measurements, the R's with weight of cut were 0.75 for the short loin and 0.77 and 0.78 for the sirloin butt and trimmed loin respectively. Results to date indicate that it is possible to predict the weight of wholesale cuts from the live animal with a good degree of accuracy and that the use of measurements might be of value in establishing objective methods for selecting cattle.

Meats Section

A. L. Anderson, *Chairman*

THE EFFECT OF VARIOUS COMBINATIONS OF SALT & SUGAR ON THE DEVELOPMENT OF RANCIDITY IN CURED BACON. A. V. Allen and T. N. Blumer, *North Carolina State College.*

This investigation was undertaken to determine the effect of rancidity development in bacon, where varying concentrations of salt and sugar were used in the

curing mixture. Two replications of eight treatments each were used, composed of varying combinations of salt and sugar ranging from 0% sugar and 100% salt to 70% sugar and 30% salt. The curing mixtures were applied at the rate of ¾ oz. per pound of meat. After curing the bacon slabs were hung in a dark, unheated room. The slabs were tested for rancidity as indicated by peroxide values every 30 days for a period of 16 months. Since no rancidity developed with any of the treatments, two more replications of 20 bacons each were cured. Ten of the bacons were cured with salt-sugar combinations ranging from 0% sugar to 100% salt and 100% sugar to 0% salt. The remaining 10 bacons were cured with salt equal in amount by weight to the salt applied in each of the salt-sugar combinations. All bacons were sliced into ¼" slices and hung in a room heated to 80° F.±50. They were tested for rancidity 2 or 3 times weekly. There were no significant differences in the length of time required for rancidity development. The taste panel results indicated that those bacons containing approximately one-half salt and sugar to slightly more salt than sugar were preferred. However, all treatments of the slab bacon were edible after 12 months' storage.

THE RELATION OF AGE AT TIME OF CASTRATION TO THE QUALITY AND YIELD OF BEEF. R. J. Deans, S. A. Husaini, Paul Gerlaugh, L. E. Kunkle and F. E. Deatherage, *Ohio Agricultural Experiment Station and the Ohio State University.*

A group of 30 male weanling calves were put on dry lot feeding. One group of ten was castrated near the beginning of the test at two months of age. A second group of ten was castrated at eight months and the third group remained as bulls to the completion of test at about 16 months of age. The three groups were slaughtered and completely cut down for edible lean meat yields. Tenderness and a number of biochemical determinations were made on the meat at 3 and 15 days *post mortem*. The yield of edible meat, quality of meat, carcass grade, efficiency of feed utilization, and chemistry of the carcasses from the three lots were determined.

AN ACCELERATED CURE FOR BACON. Verlin K. Johnson and Sleeter Bull, *University of Illinois.*

Top grade bacon ordinarily requires a 21–28 day cure at 38° F., requiring the packer to carry large inventories and provide a large amount of refrigerated storage space. The low curing temperature not only inhibits bacterial growth but also retards the speed of chemical reactions, diffusion, osmosis and capillary movement. In these experiments, a temperature of 120° F., not only inhibited bacterial growth but speeded up chemical and physical reactions sufficiently to cure bellies in a 55° pickle, to which was added sugar, sodium nitrate and sodium nitrite, in 24 hrs. Compared with dry-box-cured bacon, the quick-cured bacon had a brighter lean, but contained less sodium nitrate and sodium nitrite. There was no difference in color of fat. The amounts of sodium chloride were about the same. The palatability of the bacon from both cures was satisfactory, with no significant differences due to cure. The mean shrink of the quick-cured bacon was 3.4 percent greater than that of the box-cured bacon. The quick-cured bacon kept satisfactorily.

SOME OBSERVATIONS ON THE pH OF PORK UNDER VARIOUS CONDITIONS. John F. McCarthy and David L. Mackintosh, *Kansas State College.*

This study was undertaken to secure additional information on the pH of pork under various conditions. The experimental part was divided into five major divisions. First, the determination of the pH of ham by inserting the electrodes directly

into the hams. The next part was determining the pH value of a portion of the ham removed from the carcass. This second part was performed to establish the accuracy of pH readings made by inserting the electrodes directly into the carcass. Third, the Psoas major was removed from the carcass immediately following slaughter and pH determinations were made at intervals the following forty-eight hours. The effect of rest and feeding the hogs before slaughter on the pH of the Psoas major after slaughter was studied. The last two parts deal with the effects of repeated freezing and thawing on the pH of the Longissimus dorsi and pork sausage. The data obtained indicates that accurate pH values can be determined by inserting the electrodes directly into the tissue. The Psoas major appears to have a higher pH value than the ham. The hogs rested and the hogs fed before slaughter appear to have a greater variation in the pH of the Psoas major than the hogs slaughtered following exercise and the hogs given only water. Repeated freezing and thawing on the Longissimus dorsi appear to have little, if any effect. However, there appears to be a difference in the pH value from different locations on the loin.

THE TISSUE DEPOSITION OF CERTAIN B-COMPLEX VITAMINS AS INFLUENCED BY AUREOMYCIN AND APF IN SWINE RATIONS. A. M. Pearson, J. A. Liuzzo, R. Buchele, R. S. Glasscock, and T. J. Cunha, *University of Florida.*

Young pigs averaging approximately 35 pounds were fed on a basal corn-peanut meal ration, which was supplemented as follows: (1) 20 mg. of vitamin B_{12} per 100 pounds of feed, (2) same as lot 1 plus 9.1 grams of crystalline aureomycin per 100 pounds of feed, and (3) 454 grams of Lederle's crude APF supplement per 100 pounds of feed. The pigs were slaughtered after 54 days on feed at an average weight of 68.7, 92.3 and 86.0 pounds for lots 1, 2, and 3, respectively. After chilling for 24 hours, the carcasses were cut and a section posterior to the last rib was cut into chops, packaged, frozen and held at approximately 0° F. Tissue was removed from the frozen chops, ground with distilled water in a Waring Blender, and hydrolyzed. Microbiological determinations were made on aliquot samples for thiamine, riboflavin and niacin. The average values on a fresh basis were 6.93, 10.30 and 7.11 gamma/gram for thiamine, 1.55, 1.73 and 1.59 for riboflavin, and 77.73, 60.58 and 76.91 for niacin for lots 1, 2, and 3, respectively. Calculated to a fat-free dry basis the values for thiamine were 29.33, 44.28 and 32.57 gamma/gram, for riboflavin, 6.57, 7.48 and 7.75, and for niacin, 330.66, 259.85 and 372.84 for lots 1, 2, and 3, respectively.

FLOW SHEETS OF PREPACKAGED FRESH MEAT. M. M. Voegeli, L. J. Bratzler, and W. L. Mallmann, *Michigan State College.*

Since 1946 there have been numerous studies on prepackaged meat. These have dealt mostly with consumer opinion and retailer questionnaires. There have been no studies made from the bacteriological viewpoint. This investigation was of two parts: 1. To determine the general sanitary conditions of cooperating commercial stores by sampling the equipment and environmental surfaces where the meat was prepackaged: 2. To determine the increase in number of organisms on prepackaged meat as displayed over a 5 day period. The equipment and environmental surfaces of 2 commercial retail outlets were sampled by the swab method. The results obtained indicate that the greatest source of contamination of prepackaged fresh meat was that dealing directly with the cutting operations. Fresh pork, beef and lamb were cut and packaged in the same commercial stores. The meats were divided into 11 trials, each including 30 or more retail cuts of meat. Samples were taken

from the retail cut using a sterile cork borer. Cuts were sampled before packaging and then at 24 hour intervals from the commercial stores' display cases. Pour plates were made using T.G.E. agar after the samples were emulsified by means of a Waring Blender. The plates were incubated at room temperature and counted after 48, 72, and 120 hours. The increase in number of organisms for the 5 day display period would indicate the same trend for the 3 types of meat used. After the first 3 days of display time, the increase in numbers of organisms is greatly increased.

THE USE OF ANTIOXIDANTS IN THE FREEZER STORAGE OF FRESH PORK SAUSAGE. J. J. Wanderstock and J. I. Miller, *Cornell University*.

An investigation was conducted to ascertain the most efficient and effective method of minimizing rancidity in fresh pork sausage during freezer storage. Fresh pork, in the proportions of three parts lean to one part fat, was treated as follows; without any seasoning, completely seasoned (salt, pepper, and sage), seasoned with pepper and sage, seasoned with a commercial seasoning with and without an added antioxidant, completely seasoned with Tenox II added, and completely seasoned with NDGA and citric acid added.

The sausage was frozen in 5 ounce patties and stored at 0°F. for 3, 4, 5, 6, 7, 10, 12, and 13 months. Representative samples were removed at these times for palatability studies and for peroxide number determinations.

Peroxide number determinations were very low and inconclusive. Palatability studies for rancidity indicated a difference in average palatability scores among the samples. The differences among treatments were significant at the 5 percent level. The sausage seasoned with pepper and sage, and that seasoned with the commercial seasoning without an added antioxidant, were significantly less desirable than the untreated control. This experiment indicated that the addition of antioxidants did not significantly improve the freezer storage keeping quality of fresh pork sausage over that resulting from freezing fresh pork and seasoning it during cooking.

FAT TRANSLOCATION IN COOKED BEEF AS A RESULT OF COOKING. H. Wang, Ellen M. Rasch and Virginia Bates, *American Meat Institute Foundation*.

Ten-fifteen μ frozen sections of 1½-inch thick beef steaks of the *Longissimus dorsi* (ribeye) and *Semitendinosus* (outside round) muscles broiled to an internal temperature of 150°F. were used for investigating the effect of cooking on the physical state and distribution of intramuscular fat by tracing fat which is known to be lost from fat cells during cooking. They were stained with either Sudan IV or Nile blue sulphate. Both kinds of stained preparations disclosed that a fair amount of fat had been released from fat cells in perimysia of all sizes. The cells from which fat had escaped were either empty or partially stained by the dye. This fat, after it left the cells, did not flow to the immediate vicinity for there was no evidence of any structural elements being coated with fat. Instead, it underwent a progressive dispersion along a definite trail; the size of resulting oil droplets decreased from the source until they reached a size beyond microscopic resolution. Little of the dispersed fat extended beyond perimysial limits into the spaces surrounding individual muscle fibers. The dispersion density and total area covered by it seemed roughly proportional to the amount of fat released in a given site without apparent correlation to the size of either perimysia or of the fat island involved. Since the route of escape for the released fat is mostly by way of perimysia, much of this fat is probably still retained by the meat.

SOME CARCASS CHARACTERISTICS OF CALVES PRODUCED BY THE KENTUCKY COW-AND-CALF PLAN. E. J. Wilford, *University of Kentucky.*

The Kentucky Cow-and-Calf Plan of beef production has become very popular with the Kentucky farmers. Under this plan the dams are heavy-milking grade cows and the sires are of the purebred beef breeds. The calves are dropped in January or February and remain with their dams, on pasture, until sold in late October or early November. No exact information has been available as to the carcass characteristics of calves produced by this plan. Eighteen of these calves were slaughtered. Six of these were classed as heavy calves with live weights ranging from 468 to 514 pounds. The other 12 were classed as light beeves, weighing from 608 to 706 pounds. All animals were slaughtered three to six hours after having been taken from their dams. Dressing percentages ranged from 53.9 to 62.7 and averaged 58.8. The carcasses were graded by a federal grader as: two prime, ten choice, and six good, using the new standards. Pictures were taken of the sires, dams, calves on foot, whole carcasses, cross section of the round, and the posterior surface of the eleventh rib. The ninth, tenth, and eleventh rib cut was mechanically separated into lean, fat, and bone, as an index of the percent of these components contained in the whole carcass. The cross section of the eleventh rib was traced and the areas of lean, fat, and bone determined with the aid of a planimeter. Consumer acceptance was pronounced because of the high quality and small waste.

Nutrition Section

Wise Burroughs, *Chairman*

THE EFFECT OF SOLVENTS AND HEAT TREATMENTS UPON THE NUTRITIVE VALUE OF SOYBEAN OIL MEAL FOR SWINE. C. R. Adams, D. E. Becker, S. W. Terrill and R. J. Meade, *University of Illinois.*

The solvent and heat exposure used in the processing of the various soybean oil meals tested, respectively, were (A) hexane, untoasted; (B) hexane, 50% of regular toast; (C) hexane, regular toast, and (D) trichloroethylene, regular toast. All meals were hull-less except D. In a factorial experiment each was tested as a supplementary source of crude protein with yellow corn, alfalfa meal, and minerals for pigs on winter rye pasture from weaning to 200 lbs. All rations were fed with and without aureomycin HCl at 5 mgm./lb. Results showed that B, C and D did not differ significantly from each other but were superior to A. Apparently D possessed no toxic properties. When fed with B, C and D aureomycin stimulated a significant increase in gains from weaning to 100 lbs.; whereas, its effect to final weight was not significant. The magnitude of the response to aureomycin varied directly with the length of heat treatment applied to the soybean oil meals; supplementary aureomycin with the ration containing A failed to produce a growth response. In another test the protein efficiency technic was employed to determine the relative quality of the crude protein. Semi-purified rations containing 10% crude protein solely from these soybean oil meals and equalized for ether extract and crude fiber were fed to weanling pigs in drylot for 37 days. The daily gain per pig (lb.) and gain/lb. of protein consumed (lb.), respectively, were: (A) 0.47, 2.20; (B) 1.03, 3.81; (C) 1.19, 4.23; (D) 0.72, 3.05.

A STUDY OF THE POLYUNSATURATED FATTY ACIDS IN BLOOD PLASMA OF YOUNG DAIRY CALVES. R. S. Allen, J. H. Zaletel and N. L. Jacobson, *Iowa State College.*

Five dairy calves were allowed to remain with their respective dams for 3 days following birth and were fed whole milk thereafter. Samples of venous blood were obtained at birth and at 24-hour intervals during the subsequent 4 days and the plasma polyunsaturated fatty acids were estimated employing alkali conjugation techniques. The values for the dienoic (linoleic) acid increased markedly during the period of observation and, except for samples from newborn calves, represented the major portion of the polyunsaturated fatty acids. Trienoic (linolenic) acid was present in small amounts in most samples and no major changes in the levels of this acid were observed during the 4-day period. In plasma samples obtained from calves at birth the tetraenoic acid values were similar to those for linoleic acid. Subsequently, the tetraenoic acid levels increased slightly during the period 0 to 2 days and were relatively constant thereafter. For the 4-day samples the mean polyunsaturated fatty acid values in mg. per 100 ml. plasma were: dienoic, 28.2; trienoic, 2.7; and tetraenoic, 7.3. Traces of pentaenoic and hexaenoic acids were observed in most samples.

THE EFFECT OF SEVERAL LEVELS OF AUREOMYCIN FED TO SWINE UNDER DIFFERENT SYSTEMS OF MANAGEMENT. Guy N. Baker, Merle J. Brinegar, C. T. Blunn and A. J. Clawson, *University of Nebraska.*

Several levels of an aureomycin-vitamin B_{12} supplement (Lederle's "Aurofac," containing 1.8 grams of aureomycin and 1.8 milligrams of B_{12} per pound) were fed to 200 weanling Duroc pigs in concrete floored pens, in dry lots (soil) and in pens with fattening cattle. The pigs had received the above supplement in their creep ration until the start of the experiment. They were approximately 30% inbred and averaged 33 pounds at the start of the experiment (56 days of age). The basal diet contained approximately 18% protein and included 7% tankage, 7% distillers' solubles, 7% dehydrated alfalfa meal, 12% soybean meal, 66% corn and minerals. The levels of aureomycin-B_{12} supplement (pounds per ton) and average daily gains of the pigs on concrete for 70 days were: none-0.81, 2.5–0.92, 5.0–1.04 and 7.5–1.04. Supplement levels and gains for the pigs on soil for 54 days were: none-0.82, 2.5–1.05, 5.0–1.04 and 7.5–1.14. For the pigs behind cattle, the supplement levels and gains for 74 days were: none-0.82 and 5.0–1.01. Two levels of the above supplement were also fed to 80 similar pigs on alfalfa pasture. The basal diet contained approximately 16% protein and included 5% tankage, 5% distillers' solubles, 11% soybean meal, 78% corn and minerals. The supplement levels (pounds per ton) and average daily gains were: none-1.06, 5.0–1.23 and 10.0–1.22.

THE COMPARATIVE GROWTH RESPONSE OF BABY PIGS FED DIETS CONTAINING GLUCOSE AND XYLOSE. E. R. Barrick, G. Matrone, G. H. Wise, H. A. Stewart and S. B. Tove, *North Carolina State College and U. S. Plant, Soil and Nutrition Laboratory.*

Two-week old pigs which had been with their dams from birth were transferred to individual screen bottom cages and fed ad libitum a purified type diet containing 37.4% sugar. In the control diet "cerelose" alone was used but in the two test diets 50% of "cerelose" in one and 100% in the other was replaced by xylose. Four pigs received each diet. All animals were started on the "cerelose" diet but the two test groups were changed during a preliminary period of 7 days to their respective diets. The subsequent test period was 38 days. The pigs fed

"cerelose" grew normally and ate increasing amounts daily while the xylose fed pigs grew slowly and consumed about the same amount of feed daily throughout the test period. The average daily gain, the daily feed consumption and feed consumed per gram of gain were as follows: "Cerelose" 232g., 250g., 1.07g.; 50% cerelose and 50% xylose 90g., 208g., 2.32g.; and 100% xylose 50g., 171g. and 3.40g. No digestive disturbances were encountered and no observable abnormalities developed as a result of feeding the xylose. The hair coats of all the pigs receiving xylose became somewhat dry and rough by the end of the trial in contrast to the glossy hair coats of the control pigs. Two of the pigs receiving the high level of xylose were autopsied at the completion of the trial but they did not show any gross abnormalities.

EFFECTS OF FEEDING AUREOMYCIN TO DAIRY CALVES. E. E. Bartley, K. L. Wheatcroft, T. J. Claydon, F. C. Fountaine and D. B. Parrish, *Kansas Agricultural Experiment Station.*

Dairy calves were fed an aureomycin supplement (Lederle) at levels of 3 and 9g. per 100 lb. body wt. (daily, by capsule) from 1 to 22 wks. of age. Gains made by both groups of supplemented calves were superior to gains made by controls, but the difference between the two supplemented groups was not significant. When calves were fed 3g. of supplement, the av. wt. at the end of 22 wks. was 410% of the initial 1st wk. wt. Similarly calves fed 9g. averaged 400% of the initial wt. and the controls averaged 356%. The Ragsdale growth standard indicates an increase of 340%. The amount of TDN and dig. protein used per lb. of gain (from 1 to 12 wks.) was similar for control and supplemented groups. The av. hay consumption (per unit of body wt.) for the supplemented and control groups was similar. However, the supplemented calves averaged about 22% more grain consumption (per unit of wt.) than the controls averaged. Large daily doses (200 to 800 mg. aureomycin HCl/100 lb. calf wt.) were fed to a few 12 to 16 wk. old calves without producing any visible detrimental effects. One 16 wk. old calf (not previously supplemented) received 2500 mg. aureomycin daily for 4 wks. No deleterious effects on feed consumption, rumination or growth resulted. Data on the effect of aureomycin on digestibility of feeds will be presented. In rumen microflora studies direct microscopic examinations did not indicate a consistent difference between controls and aureomycin-fed calves. However, preliminary cultural studies suggested that there were some differences.

THE GROWTH RESPONSE OF THE PIG TO A DIETARY SOURCE OF VARIOUS ANTIBACTERIAL AGENTS AND TO INTRAMUSCULAR INJECTIONS OF PROCAINE PENICILLIN. D. E. Becker, S. W. Terrill, D. E. Ullrey and R. J. Meade, *University of Illinois.*

In experiment 1 a diet consisting of yellow corn, soybean oil meal, bone meal, vitamin A and D supplement, mineral mixture, vitamin B_{12} supplement, choline chloride concentrate, riboflavin, calcium pantothenate, and niacin was group fed to pigs from weaning to 100 pounds in drylot. Additions of aureomycin, neomycin, procaine penicillin, and chloramphenicol were made at 5 mg. per lb. of feed. Aureomycin and procaine penicillin were of equal activity and stimulated a statistically significant increase in rate of gain over the control group. Neomycin and chloramphenicol produced only a slight increase in growth rate. Experiments 2 and 3 were designed to study the effect of oral and intramuscular administration of procaine penicillin upon the rate of gain. Weanling pigs were group fed a diet composed of yellow corn, soybean oil meal, corn distillers' solubles, meat scraps, alfalfa meal, fish solubles, mineral mixture, and a vitamin A and D supplement for

six weeks in drylot. In experiment 2 the intramuscular injection of an aqueous suspension of procaine penicillin G at the rate of 200,000 units on alternate days failed to influence the rate of gain. However, in experiment 3 the intramuscular injection of a similar quantity of procaine penicillin G in sesame oil containing 2% (W/V) aluminum stearate gave a statistically significant increase in rate of gain, whereas, the growth response yielded by dietary procaine penicillin at 5 mg./lb. was not statistically significant. There were no additive effects of a dietary and parenteral source of procaine penicillin for the pig.

EFFECT OF ARGININE, LEUCINE, PHENYLALANINE, AND VALINE ON THE GROWTH OF WEANLING PIGS. W. M. Beeson, E. T. Mertz, and H. D. Jackson, *Purdue University Agricultural Experiment Station.*

Fifteen Duroc boar pigs averaging 31 lb. were divided into five lots. Lot I (control) received a purified ration containing arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, valine, and diammonium citrate as the sole source of protein nitrogen. The remaining lots were fed the same ration except arginine was left out of the diet for Lot II, leucine for Lot III, phenylalanine for Lot IV, and valine for Lot V. On the complete diet (Lot I), the animals made an average daily gain of 1.2 lb./pig (28 days), on arginine-deficient diet; 0.7 lb./pig (28 days), on leucine-deficient diet; —0.2 lb./pig (21 days), on phenylalanine-deficient diet; 0.0 lb./pig (28 days), and on valine-deficient diet; —0.2 lb./pig (21 days). When the animals in Lots II to V inclusive were fed all ten of the so-called "essential" amino acids listed above (ration for Lot I) they made an average daily gain of 0.6 lb./pig. These data show for the first time that in addition to histidine, isoleucine, lysine, methionine, threonine, and tryptophan, the amino acids arginine, leucine, phenylalanine, and valine are also required for optimum growth of weanling pigs. These findings confirm our previous research which indicated that the amino acids which are commonly designated as "non-essential" for the rat are likewise dispensable for early growth of pigs.

UTILIZATION BY STEERS OF UREA NITROGEN IN RATIONS CONTAINING DIFFERENT CARBOHYDRATE FEEDS. M. C. Bell, Willis D. Gallup and C. K. Whitehair, *Oklahoma Agricultural Experiment Station.*

The value of urea as a source of nitrogen in rations containing different carbohydrate feeds was determined in a series of digestion and nitrogen balance trials with steers. The carbohydrate feeds used in formulating the different rations were ground yellow corn, dehydrated sweet potatoes, cracked milo, rolled barley, cane molasses and combinations of cane molasses and ground corn. Each of these feeds was combined with prairie hay and sufficient protein supplement to provide basal rations having 8% of crude protein. Urea in the form of "Two-Sixty-Two" was added to each ration in amounts required to provide a total of 11% protein equivalent. Six or more trials were conducted with each basal and each urea-supplemented ration. There were some differences among the basal rations in palatability and digestibility of nutrients attributed to differences in the carbohydrate feeds. Addition of urea had very little effect on apparent digestibility of nutrients, other than protein (N x 6.25) which was increased in all rations. It improved nitrogen retention to a significant extent when added to each ration, a greater improvement being made when it was added to the corn ration than when it was added to the cane molasses ration. The results demonstrate the usefulness of urea as a nitrogen supplement in rations adequately supplied with carbohydrates from widely different sources.

"EFFECT OF ANTIBIOTICS AND VITAMIN B_{12} ON THE PANTOTHENIC ACID REQUIREMENT OF GROWING-FATTENING SWINE". R. W. Bennison, Damon Catron and Helen M. Maddock, *Iowa Agricultural Experiment Station.*

Two experiments were conducted in drylot to determine the effects of antibiotics and vitamin B_{12} on the pantothenic acid requirement of growing-fattening swine. Ten replicated lots of 4 pigs each (2 Duroc and 2 Landrace X Duroc) were self-fed from weaning to 200 pounds. Five levels of pantothenic acid (0, 1, 2, 3 and 4 mg.) with and without a combination of 10 mg. each of aureomycin, streptomycin, terramycin and penicillin, were added per pound of total ration. The basal ration consisted of corn, soybean oil meal, minerals, vitamins A, D_3, E, K and 11 water-soluble vitamins including 10 mcg. vitamin B_{12}. The results indicated no significant differences in gains or feed efficiency between the pigs fed the different levels of pantothenic acid. Antibiotics increased daily gains from 1.64 to 1.89 pounds. Carcass studies revealed no significant differences in tissue moisture, backfat or body length due to ration treatment. A second experiment, a 2 x 2 x 2 factorial, was conducted to measure the effects of adding 3.5 mg. pantothenic acid, 10 mcg. vitamin B_{12} and 10 mg. of aureomycin per pound of ration and possible interactions. A 14% all-plant protein ration containing added vitamins A, D_3, riboflavin, niacin and choline was self-fed to 8 duplicate lots of 4 Landrace X Duroc pigs each for 10 weeks. The pigs receiving aureomycin gained significantly faster than those receiving no aureomycin. Vitamin B_{12} and pantothenic acid did not increase gains significantly and there were no significant interactions. No goose stepping developed in either experiment, although the basal pigs in the second experiment appeared less thrifty than those receiving supplementation.

FACTORS AFFECTING THE DIGESTIBILITY OF CELLULOSE OF POOR QUALITY HAY. Orville G. Bentley, Anthony Latona, Peter DePaul, and C. H. Hunt, *Ohio Agricultural Experiment Station.*

The effect of feeding a poor quality hay on the biochemical functions of rumen microorganisms *in vitro* has been studied using the artificial rumen technique developed by Burroughs *et al.* The poor hay used was late-cut, mixed hay, chiefly timothy (5.5% protein). A fistulated steer previously fed good quality, second and third cutting alfalfa hay was placed on this poor hay ration. Salt was provided free choice. The *in vitro* activity of the rumen microorganisms, as measured by ammonia utilization and cellulose digestion, was determined prior to and following the change in hay ration. At the end of one week, ammonia (urea) utilization had dropped 25% and the rate of cellulose digestion had decreased 90% during the first four weeks of poor hay feeding. Volatile fatty acid production dropped 30% and riboflavin synthesis was reduced by 14%. While on the poor hay, the steer lost weight, probably due to a combination of reduced feed intake and lowered digestibility of the hay. The addition of starch to the *in vitro* fermentation mixture accentuated the difference observed between inocula from good hay or poor hay-fed animals. Supplementing the poor quality hay with steamed bone meal, 2; ground limestone, 2; and salt, 1, free choice, resulted in *in vitro* microorganism activity similar to that observed when the alfalfa hay was fed. Removing the mineral supplement again lowered the activity of the rumen organisms. Preliminary evidence indicate that the low phosphorus content of the poor quality hay is a limiting factor in cellulose digestion.

CREEP FEEDING A RATION OF GRAINS, PROTEINS AND SUPPLEMENTARY B-VITAMINS TO SUCKLING LAMBS IN DRY LOT. L. H. Blakeslee, H. A. Henneman, R. W. Luecke, *Michigan State College.*

Records of necropsied lambs show that the rumen may not be functional at one month of age or older while consuming milk. Young nursing lambs may there-

fore possess similar nutritional requirements to simple stomached animals. This report is on two lots of 20 suckling lambs each, which were divided as equally as possible with their dams when the oldest lambs were one month of age. Both lots of lambs were given access to a creep containing a mixture of corn, oats, protein supplements, beet pulp, wheat by-products, A. & D. Vitamins and mineral salt. The protein content of this ration was approximately 13.6% and the fiber content about 7%. The experimental lot received in 100 pounds of the foregoing ingredients 0.5 lb. of Lederle's 249C B-vitamin supplement. The control lot received the same mixture but none of the B-vitamin supplement. No record was kept of the amount of feed consumed but the troughs in the creep were cleaned often and a small amount of the creep mixture added as necessary. The lambs were given free access to the mixture from March 29th until going to pasture May 7th. The lambs receiving the B-vitamin gained 0.347 lb. per lamb per day over the 39 day period while the control lambs gained only 0.25 daily per lamb. A comparison of the lambs indicated the faster gaining lot were more thrifty with a coat of wool showing more luster and a more healthy appearance.

THE VALUE OF METHIONINE, LYSINE AND VITAMIN B_{12} AS SUPPLEMENTS TO A CORN-SOYBEAN MEAL DIET FOR PIGS AND RATS. J. C. Blight and W. C. Powick, *U. S. Dept. of Agriculture.*

Feeding trials were conducted with weanling pigs and with rats to determine the value of methionine, lysine and vitamin B_{12} as supplements to a corn-soybean oil meal diet. The experiments were set up as 2^3 factorial type which, with an economy of animals, permits a statistical evaluation of the effects of all possible combinations of the three factors. The basal diet was composed of yellow corn, soybean oil meal, minerals (including trace elements), and all known nutritionally important vitamins, except vitamin B_{12}. The average daily gains and feed per 100 pound gain obtained for each lot of pigs were: (A) basal, 1.54 pounds, 285 pounds; (B) basal plus methionine, 1.79 pounds, 280 pounds; (C) basal plus vitamin B_{12}, 1.39 pounds, 321 pounds; (D) basal plus methionine and vitamin B_{12}, 1.78 pounds, 278 pounds; (E) basal plus lysine, 1.61 pounds, 297 pounds; (F) basal plus lysine and methionine, 1.58 pounds, 286 pounds; (G) basal plus lysine and vitamin B_{12}, 1.57 pounds, 297 pounds; and (H) basal plus lysine plus methionine plus vitamin B_{12}, 1.72 pounds, 299 pounds. Analysis of the data showed that the addition of methionine alone or in combination with vitamin B_{12} significantly increased gains. In the presence of lysine, the addition of methionine was without effect. The addition of vitamin B_{12} did not significantly affect the growth rate. The addition of the three factors alone or in the various combinations had no measurable effect on the growth rate of rats.

THE VALUE OF VITAMIN B-12, DL-METHIONINE, PENICILLIN, AND AUREOMYCIN IN MILK REPLACEMENT FORMULAE FOR DAIRY CALVES. Solomon Bloom and C. B. Knodt, *Pennsylvania Agricultural Experiment Station.*

In the first trial 24 male Holstein calves 5 days of age were divided into four comparable groups on the basis of height at the withers, body weight, and chest circumference, and were fed a recommended milk replacement supplemented as follows: Group I—received the basal replacement, group II—basal replacement plus 50 g. of a vitamin B-12 supplement per 100 lbs. (6 mg. B-12/lb. equivalent), group III—basal diet plus 0.3% DL-methionine, and group IV—basal replacement plus potassium-penicillin (10 p.p.m.). Under the conditions of this experiment it does not appear that the use of a milk replacement supplemented with vitamin B-12

or DL-methionine improved the rates of growth in the calves studied. Statistically significant lowered growth rates were obtained with the potassium-penicillin fed calves. This group also consumed much smaller quantities of starter than that eaten by the other groups in this trial. In a second trial 48 Holstein male calves were divided into 8 similar groups, were fed hay and starter as in trial I, and in addition were fed a recommended milk replacement as follows: Group I—(control), no supplementation, group II—1 mg. crystalline vitamin B-12 per 100 lbs. replacement, groups III, IV, and V—increasing levels of 0.5 g., 1.0 g., and 2.0 g. crystalline HCl aureomycin per 100 lbs. replacement respectively, and groups VI, VII, and VIII—increasing levels of 0.5 mg. vitamin B-12 plus 0.5 g. aureomycin, 1 mg. vitamin B-12 plus 1.0 g. aureomycin, and 2 mg. vitamin B-12 plus 2.0 g. aureomycin per 100 lbs. replacement respectively.

THE EFFECT OF VITAMIN B_{12}, STREPTOMYCIN AND AUREOMYCIN ON GROWTH AND METABOLISM OF THE RAT. John W. Bratzler and Alex Black, *Pennsylvania State College.*

In each of two experiments three groups of 12 weanling, male, albino rats were fed rations of the same composition except for supplements of B_{12} and/or antibiotics. The rations were fed ad libitum and were composed of purified ingredients with the exception of the protein which was entirely of plant origin. Animals received the experimental rations until they had attained a live weight of approximately 256 grams at which time they were slaughtered and the bodies subjected to the analyses required for the determination of the total heat production by the body balance procedure. Average values for the efficiency of feed utilization (grams of feed per gram of gain) and number of days required to attain the above live weight were, respectively: unsupplemented, 3.98 and 71; aureomycin, 4.60 and 79; B_{12} and aureomycin, 2.68 and 41; streptomycin, 4.84 and 82; B_{12}, 2.86 and 41; and B_{12} and streptomycin, 2.74 and 39. Results on the last three groups showed that addition of vitamin B_{12} had a significant influence on the utilization of energy. The growth rate was doubled with approximately 6% less of the feed energy being lost as heat. Streptomycin had an insignificant influence on the energy metabolism. The mode of action of vitamin B_{12} in the case of the rat appears to be primarily one of increasing feed consumption, making available a greater percentage of the total feed energy for body gain than is the case with the animals not receiving this particular supplement.

EFFECTS OF PENICILLIN AND STREPTOMYCIN ON THE GROWTH RATE AND BACTERIAL COUNT IN THE FECES OF SWINE. J. H. Brides, I. A. Dyer and W. C. Burkhart, *University of Georgia.*

Five groups of 10 weanling Duroc and Duroc-Poland China cross-bred pigs each were self-fed in drylot to an average final weight of 100 pounds. All rations contained 20% crude protein and were fortified with Vitamins A, D, B_1, B_2, B_{12}, niacin, pantothenic acid and choline. Rations 1–5 respectively were composed as follows: (1) 63% ground corn, 35% "degossypolized" cottonseed meal, and 2% mineral mixture; (2) same as lot 1 plus penicillin; (3) same as lot 1 plus streptomycin; (4) same as lot 3 plus penicillin; (5) 64% ground corn, 35% solvent soybean oil meal and 2% mineral mixture. The average daily gains and feed efficiency of pigs in lots 1–5 were: .79, 388; 1.05, 351; 1.15, 329; .92, 344; and 1.27, 287 pounds respectively. The average colony count in feces from lots 1–5 were: 54, 271, 59, 83 and 61 million per gram respectively.

THE EFFECT OF TYPE OF RATION ON THE PENICILLIN REQUIREMENT FOR GROWING-FATTENING PIGS. J. E. Briggs, Roy Elrod, and W. M. Beeson, *Purdue University.*

In a weanling pig experiment (summer) levels of 0, 1.0, 2.5, and 5.0 mg. of procaine penicillin (per lb. of finished feed) were added to an 18% well-fortified mixed animal and plant protein ration (Basal A) or an 18% well-fortified straight plant protein ration (Basal B). Basal A contained 74.00% yellow corn, 10.26% expeller soybean meal, 5.13% Menhaden fishmeal, 5.13% meat and bone scraps, 2.56% cottonseed meal. 2.56% dehydrated alfalfa meal, A and D oil, Merck's B_{12} Concentrate, riboflavin, pantothenic acid, and niacin, plus steamed bonemeal, ground limestone, and iodized salt fed free choice. Basal B was essentially the same formula as Basal A excepting expeller soybean meal replaced the animal-plant protein supplements. The level of protein in all diets was reduced as the pigs matured. The average daily gains and feed per 100 lb. gain, respectively, for each lot of ten purebred Hampshire pigs each (initial weight, 44 lb.) for the first 8 weeks in concrete pens were: (1) Basal A 1.19 lb., 336 lb.; (2) Basal A+1.0 mg. penicillin 1.26 lb., 315 lb.; (3) Basal A+2.5 mg. penicillin 1.39 lb., 310 lb.; (4) Basal A+5.0 mg. penicillin 1.48 lb., 307 lb.; (5) Basal B 1.13 lb., 319 lb.; (6) Basal B+1.0 mg. penicillin 1.10 lb., 340 lb.; (7) Basal B+2.5 mg. penicillin 1.34 lb., 318 lb.; (8) Basal B+5.0 mg. penicillin 1.38 lb., 302 lb. The pigs on the two higher levels of penicillin in either basal ration gained markedly faster on less feed, and consumed ⅓ to ½ lb. more feed daily than those fed the two lower levels of penicillin. So far the differences in water consumption between the groups were not significant.

ANTIBIOTIC STUDIES WITH SWINE IN DRY LOT AND ON ALFALFA PASTURE. Merle J. Brinegar and Donald R. Warner, *University of Nebraska.*

Antibiotic-vitamin B_{12} supplements were added to (A) an 18% protein diet (15% after 125 lb.) containing corn, soybean meal, 5% dehydrated alfalfa and added minerals, riboflavin, pantothenic acid, niacin and choline and to (B) a similar diet with 5% tankage and 5% distillers' solubles replacing soybean meal. The equivalent levels of antibiotics (gm)-B_{12} (mg) per ton of diet and daily gains (lb.) of 67-day-old pigs (41 lb. to 202 lb.) in concrete-floored pens were: none-19, A 1.45, B 1.43; aureomycin 6–7, A 1.57, B 1.59; penicillin 3–19, A 1.57, B 1.68; and terramycin 10–18, A 1.65, B 1.70. In another trial, supplements were added to a corn, soybean meal, 5% tankage, 5% dehydrated alfalfa diet including added minerals, riboflavin, pantothenic acid and niacin. The results from 41-lb. pigs (59 days old) for 60 days, presented as above, were: none-19, 1.07; aureomycin 10–19, 1.42; terramycin 10–19, 1.38; bacitracin 10–19, 1.26; and penicillin 3–19, 1.20. A supplement equivalent to 15 gm. terramycin was tested with 65-day-old pigs (40 lb.) on alfalfa pasture. The ration contained corn, 9% soybean meal, 9% tankage, salt and added B_{12}. The daily gains for 62 days were 1.29 lb. and 1.37 lb. respectively, for the basal and supplemented lots. The same diet was tested with 60-lb. pigs (76 days old) for 53 days. Lots were pair fed on pasture at 85% of normal consumption. Daily gains were: basal, 1.24 lb.; plus 20 gm. terramycin per ton, 1.33 lb. It was observed that the pigs receiving the supplement consumed more pasture. Feed utilization of all lots receiving antibiotic supplements was more efficient than that of the controls.

THE EFFECT OF AUREOMYCIN ON THE RATE OF GAIN AND EFFICIENCY OF FEED UTILIZATION BY GROWING-FATTENING SWINE. P. B. Brown, D. E. Becker, L. E. Card, and S. W. Terrill, *University of Illinois.*

Twenty-four weanling Hampshire barrow pigs were individually fed in drylot a ration consisting of yellow corn, meat scraps, soybean oil meal, dried corn distillers' solubles, alfalfa meal, fish solubles, minerals, and a vitamn A and D supplement. Six pigs in Lot 1 were fed the control ration and were pair fed for equal feed intake with pigs in Lot 2 which received aureomycin. Similarly, six pigs in Lot 3 were full fed the control ration and pairmates in Lot 4 received the supplemented ration on the same basis. Supplemental aureomycin HCl was supplied at a level of 10 mg./lb. of ration. The average daily gain (lb.) average daily feed intake (lb.), and feed/lb. of gain (lb.), respectively, were: For the initial nine weeks of the test—Lot 1, 1.00, 2.76, 2.76; Lot 2, 1.03, 2.76, 2.69; Lot 3, 0.98, 2.70, 2.75; Lot 4, 1.35, 3.64, 2.67. From weaning to 200 lb. liveweight—Lot 1, 1.27, 4.62, 3.65; Lot 2, 1.33, 4.62, 3.48; Lot 3, 1.33, 4.59, 3.50; Lot 4, 1.53, 5.30, 3.47. There were no statistically significant differences in these data for the pair fed pigs; whereas, the daily gain and daily feed intake of Lot 4 were both significantly greater than the same figures for Lot 3. Apparently the predominant influence of dietary aureomycin in the healthy pig is mediated through an increased daily feed consumption. Hemoglobin determinations and rate of feed passage through the alimentary tract (as measured by excretion time of Fe_2O_3) were not different between the control and supplemented lots. Nitrogen and energy balance studies were also conducted.

SOME CHARACTERISTICS OF THE DIFFERENT BACTERIA PRESENT IN THE RUMEN OF CATTLE ON A CONSTANT RATION. M. P. Bryant, *U. S. Department of Agriculture.*

Preliminary results obtained from the study of the rumen contents of cattle maintained by the Bureau of Dairy Industry at Beltsville, Maryland, show that 51 different kinds of bacteria have been found in 102 cultures isolated. Samples of rumen contents were collected by stomach tube at 11 A.M., diluted through 10^{-9} in anaerobic dilution blanks and inoculated into a glucose cellobiose agar containing 40 percent rumen fluid. After three days incubation at 39°C., colonies from 10^{-8} and 10^{-9} dilution tubes were inoculated into further dilution series to establish culture purity. Morphological types included various rod forms, cocci, oval shaped organisms and spirochetes. Of the 102 cultures isolated, 101 were anaerobic, 28 were motile, 5 produced hydrogen sulfide, 26 liquefied gelatin, 15 digested cellulose rapidly, 43 hydrolyzed starch, 76 produced acid from glucose, 69 produced acid from cellobiose and 40 produced acid from xylose. Some of the different kinds of bacteria studied were encountered frequently but the majority were found less frequently or only once. The results obtained indicate the complexity of the bacterial flora in the rumen of cattle on a single diet.

THE EFFECT OF VITAMIN B_{12} AND AUREOMYCIN WHEN FED WITH HIGH, INTERMEDIATE, AND LOW PROTEIN LEVELS TO SWINE. J. E. Burnside, R. H. Grummer, P. H. Phillips, and G. Bohstedt, *University of Wisconsin.*

Data have been secured to determine the effect of crystalline vitamin B_{12} and crystalline aureomycin when fed to pigs from weaning to market weight on rations consisting of corn, SBOM, alfalfa meal, and minerals. These rations were fed at 3 levels of protein to 12 groups of 8 pigs each. The lots within each protein level consisted of the basal ration, basal+B_{12}, basal+B_{12}+aureomycin, and basal+aureomycin. The initial crude protein contents of the rations were 20%, 16%,

and 12%. When each lot averaged 75 lbs. the protein content was lowered to 17%, 13%, and 10% respectively; and again when each lot averaged 125 lbs. to 14%, 11%, and 9.5% respectively. The pigs were slaughtered as each lot averaged 213.0 lbs. Crystalline vitamin B_{12} was mixed in the ration at the rate of 20 γ/kg. and crystalline aureomycin at the rate of 20 mg./kg. Blood samples were taken from each pig on the day of the protein change and on the day the lot averaged 213.0 lbs. Hemoglobin, total plasma protein, and plasma albumin and globulin were determined on the blood of each pig. Vitamin B_{12} was of little or no help in increasing gain, feed efficiency, hemoglobin, or total plasma protein. Aureomycin was of no help to the high protein pigs after a weight of 75 lbs. However, the performance of the other lots was increased as judged by the above criteria. Aureomycin+B_{12} at all protein levels gave a slightly larger increase in hemoglobin and total plasma protein than did either one alone.

"RE-EVALUATION OF PROTEIN LEVELS FOR GROWING-FATTENING PIGS IN DRYLOT." Damon Catron, A. H. Jensen and Helen M. Maddock, *Iowa Agricultural Experiment Station.*

Sixteen lots of 8 pigs each were fed a corn-soybean oil meal ration supplemented with minerals and vitamins including B_{12} from weaning to 200 pounds in concrete drylot. Initial protein levels were 20, 18, 16 and 14% with each level of protein reduced 3% when the pigs reached 75 pounds and 150 pounds. Two lots of pigs on each level of protein received 10 mg. of aureomycin per pound of ration. There were no significant differences in gains of the pigs on the various levels of protein receiving aureomycin. In the absence of aureomycin, the percent protein in the ration significantly affected the average daily gains at $P=0.05$ as measured by the quadratic regression. Starting the pigs at 16% protein produced an average daily gain of 1.63 pounds; 0.1 pound more than either the 20% or 14% starting protein levels. Aureomycin increased daily gains 0.12 pound and decreased feed requirement per 100 pounds gain by 23 pounds. Back fat, length, depth and percent of lean measured on 24 carcasses revealed no significant differences between treatments. A factorial experiment was conducted with a leaner type hog to determine the effects of 10 mg. aureomycin and 10 mcg. vitamin B_{12} per pound of ration on protein requirements. Sixteen lots of 5 Landrace X Duroc pigs each were fed for 8 weeks corn-soybean oil meal rations of 20, 16, 12 and 8% protein. Both aureomycin and vitamin B_{12} increased averaged daily gains but there was no significant interaction. Starting pigs on 16% all-plant protein rations again produced excellent growth. An all-corn ration supplemented with vitamins, including B_{12} and aureomycin was inadequate for weanling pigs.

"EFFECTS OF ANTIBIOTICS ON NUTRIENT ABSORPTION IN SWINE." Damon Catron, M. D. Lane, Loyal Payne and Helen M. Maddock, *Iowa Agricultural Experiment Station.*

Two experiments involving 20 Duroc pigs were completed on the effect of antibiotics on nutrient absorption in swine. Littermate, weanling pigs were fed a fortified corn-soybean oil meal ration for 5 weeks. After 3 weeks on experiment, blood samples were drawn by tail bleeding before and at intervals after the oral administration of glucose. In the first experiment, lot 1 receiving the basal ration gained 1.12 lb. per day and lot 2 receiving the basal plus 5 mg. of aureomycin per lb. of ration gained 1.32 lb. per day. The average blood glucose values for duplicate bleedings of unfasted pigs which received 30 gm. of glucose were for lot 1, 72.1, 84.2 and 88.4 mg. % and lot 2, 73.3, 107.9 and 96.8 mg. % for the normal, 20- and 40- or 60-minute bleedings, respectively. The 20-minute value of lot 2 was significantly

greater than lot 1 at P=0.05. Two more bleedings of the same pigs under fasting conditions showed average blood glucose levels of 53.4, 92.5 and 104.8 mg. % for lot 1 and 52.1, 79.2 and 93.2 mg. % for lot 2 at normal, 20 and 40 minutes, respectively. The 20-minute level of lot 1 was significantly greater than lot 2 at P=0.05. In a second experiment the basal, basal plus 5 mg. aureomycin, basal plus 500 mg. of combined antibiotics and a chemotherapeutic per pound of ration produced daily gains of 0.86, 1.07 and 1.54 lb., respectively. The pigs were unfasted and received 0.6 gm. of glucose per pound of body weight. The average blood glucose values from 2 bleedings were 74.9, 96.1 and 99.4 for lot 1, 79.5, 100.4 and 90.0 for lot 2 and 87.9, 97.7 and 93.9 mg. % for lot 3 at normal, 30- and 60-minute bleedings, respectively.

VITAMIN E DEFICIENCY IN THE LAMB. R. Culik, F. A. Bacigalupo, F. Thorp, Jr., R. W. Luecke, and R. H. Nelson, *Michigan State College.*

A liquid, purified diet was used to study vitamin E deficiency in 51 young suckling lambs. The source of fat in the diet of the first group was commercial lard. The deficiency symptoms appeared in 30–75 days. In the second and third groups molecular distilled lard, very low in vitamin E, was used and the symptoms were observed in 20–55 days. The symptoms of vitamin E deficiency were characterized by disturbances in locomotion, stiffness, paralysis, pneumonia and sudden death. Blood analysis showed low tocopherol levels. *Post mortem* examinations revealed dystrophy of the skeletal and cardiac muscle. The lesions in the heart were invariably most pronounced in the right ventricle. Microscopic examinations of the tissues showed degeneration and necrosis of the skeletal and cardiac muscle together with fatty degeneration of the liver and kidney. Addition of 100 mg. of alpha-tocopherol to the diet every other day protected 12 positive control lambs from muscular dystrophy. An initial dose of 500 mg. of alpha-tocopherol and 100 mg. administered every other day to eight depleted lambs alleviated the symptoms in 3–5 days. Microscopic examination of the tissues from lambs treated for 30–40 days revealed almost complete regeneration of the muscles. While this experimental work was in progress, the symptoms and degenerative changes of the musculature of lambs affected with so-called "Stiff-Lamb" disease under field conditions were also studied. The condition known as "Stiff-Lamb" disease as observed in the field appeared to be identical in every respect with nutritional muscular dystrophy produced on vitamin E deficient diet.

METHIONINE AS A SUPPLEMENT TO SOYBEAN PROTEIN FOR WEANLING PIGS. L. V. Curtin, J. K. Loosli, H. H. Williams, and J. P. Willman, *Cornell University.*

Two experiments were conducted to study the effect of adding DL-methionine to a soybean meal-purified diet for weanling pigs. In addition to soybean meal, the ration contained starch, cerelose, ruffex, lard, minerals, and all known required vitamins except vitamin B_{12}. The basal ration contained 0.31% methionine, 0.38% cystine, 0.15% choline, and 22% protein. Four lots in each experiment were fed rations supplemented with 0.0, 0.1, 0.3, and 0.5% DL-methionine. Each ration was fed to a total of 12 pigs in the two experiments: one was an individual feeding test (5 pigs per lot), and the other was a group feeding trial (7 pigs per lot). The average daily gain and the feed required per hundred pounds gain in the two trials for each of the four levels of methionine were 0.86, 0.90, 0.90, 0.92 pounds and 269, 246, 263, 252 pounds, respectively. Nitrogen balance data were also obtained by two 5-day collection periods for two pigs receiving each diet. The growth and N-balance data indicate that for the soybean meal used, there was no advantage in adding

supplemental DL-methionine in the 22% protein ration for growing-fattening pigs. Moreover, the data indicate that the DL-methionine requirement for growing-fattening pigs does not exceed 0.31% when the diet contains 0.38% cystine.

"PREPARATION OF FEEDS. GRINDING VS. PELLETING OF RATIONS FOR SWINE." W. E. Dinusson, Merle R. Light, Earle W. Klosterman, and M. L. Buchanan, *North Dakota Agricultural College.*

In initial trials of a project designed to study methods of increasing the value of barley and oats for swine feeds, thirty Duroc pigs averaging 47 to 48 pounds in weight were allotted at random into three lots. These pigs were self-fed three rations to compare the value of pulverized barley, ground corn, and pelleted pulverized barley. It was thought that by pulverizing the barley to minimize the effect of fiber, and pelleting to increase the palatability of a dusty mixture the feeding value might be increased. The control ration consisted of coarsely ground yellow corn 73%, dehydrated alfalfa 5%, meat scraps 5%, soybean oil meal 16%, salt and mineral supplement 1% plus a vitamin A and D supplement. The barley rations consisted of pulverized barley 81%, dehydrated alfalfa 5%, meat scraps 5%, soybean oil meal 8%, salt and mineral supplement 1% plus vitamins A and D. The control pigs gained 1.62 pounds per day and required 4.09 pounds of feed per pound of gain. Those on pulverized barley gained 1.57 pounds per day and took 4.09 pounds of feed per pound of gain. The lot receiving the pelleted pulverized barley ration gained 1.79 and required 3.39 pounds of ration per pound of gain. The cost of pelleting was more than offset by increased gains and feed efficiency. In a succeeding trial nearing completion similar rations are used plus a medium ground barley ration and a pelleted corn ration. Two lots of five pigs each are fed each ration. For the rations repeated the trends are similar. Of the five treatments the lots receiving the pelleted corn and pulverized unpelleted barley rations have gained the least to date.

EFFECT OF FEEDING VARIOUS PERCENTAGES OF ARTIFICIALLY-DEHYDRATED ALFALFA MEAL ON GROWTH AND CAROTENE INTAKE OF DAIRY CALVES. K. L. Dolge, H. D. Eaton, J. E. Avampato, R. D. Mochrie and F. I. Elliott, *University of Connecticut.*

Thirty-two 7-day old Guernsey and Holstein calves were allotted into 4 groups and fed rations consisting of a standard calf starter containing: (1) 7%; (2) 25%; (3) 50% and (4) 75% artificially dehydrated alfalfa meal. In addition calves receiving the 7% starter (1) were fed *ad libitum* U. S. no. 2 alfalfa hay; and Guernseys were limited to 2.5 lb. starter daily and Holsteins to 3.0 lb. The other calves (2), (3) and (4) were fed their respective rations *ad libitum*. Total lb. feed consumed thru 105 days, adjusted for the initial liveweight at 7 days, was for (1) 368; (2) 438; (3) 325 and (4) 276. Daily intake of μg. carotene per lb. of mean bodyweight was for (1) 72; (2) 132; (3) 235 and (4) 350. Mean liveweight, lb., and height at withers, inches, at 105 days of age adjusted for 7 day values were for (1) 209; 35.1; (2) 231, 35.1; (3) 202, 33.8 and (4) 172, 32.6 respectively. Estimation of vitamin A stores, by feeding a vitamin A depletion ration from 105 to 126 days of age and predicting time required for plasma vitamin A to decrease to μg.%, showed (1) to have sufficient vitamin A for 6.6 weeks, (2) 7.5 weeks, (3) 8.5 weeks and (4) 5.7 weeks. It appears from a comparison of the rations containing 25%, 50% and 75% alfalfa meal that growth is inversely related to the level of alfalfa in the ration and that maximum utilization of carotene in alfalfa occurs between the 25% and 75% levels.

FOLIC ACID DEFICIENCY IN THE LAMB. Harold H. Draper and B. Connor Johnson, *University of Illinois.*

A series of newborn lambs maintained on a "synthetic milk" diet deficient in folic acid developed a syndrome characterized by leucopenia and diarrhea followed in most cases by pneumonia and death. White cell regeneration was induced by the administration of folic acid but no detectable response was obtained to formyl folic acid. "X-methyl" folic acid was effective as an antimetabolite when administered early in the experimental period and 4-amino folic acid produced a rapid depression in leucocyte levels followed by a gradual regeneration which occurred in spite of increased doses of the antivitamin. The "citrovorum factor" was effective in reversing the depressing effect of aminopterin on white cell levels in the blood. Megaloblastic cells were absent from the bone marrow of folic acid-deficient animals. The results obtained demonstrate that folic acid is an essential nutrient for the lamb.

SOME OBSERVATIONS ON EFFECTS IN FATTENING LAMBS OF HIGH VITAMIN D AND DIETARY SILICATE ON FACTORS ASSOCIATED WITH FORMATION OF URINARY CALCULI. I. P. Earle and Ivan L. Lindahl, *U. S. Dept. of Agriculture.*

Results are presented of observations of effects in fattening lambs of supplementary vitamin D and silicate on the occurrence of urinary calculi and on factors believed to be involved in their formation. The factors considered were the levels of mineral in the blood, the reaction of the urine, the excretion of minerals in the urine and changes in the urinary tract. Four lots of six lambs each were used. Lot 1 received the basal diet only; lot 2, the basal diet supplemented with 15,000 I.U. of vitamin D; lot 3, the basal diet supplemented with 1 percent sodium silicate; and lot 4 received supplements of both vitamin D and sodium silicate. Two-thirds of each lot were slaughtered after 56 days on full feeding and the remainder after 72 days. Collections of urine were made for 6-day periods from lambs in each lot for the determination of the daily excretion of minerals. No effects attributable to the various treatments were observed on the reaction of the urine. The lambs in the silicate supplemented groups showed a markedly higher level of serum magnesium and slightly higher levels of both inorganic phosphorus and silica. Half the lambs in lot 2 and two-thirds of those in lot 4 showed definite changes in kidneys with some deposition of crystalline material in the pelvis of the kidneys. Calculi consisting of magnesium phosphates were found in the bladders of one-third of the lambs in lot 3. Results of urine analyses indicate that the silicate intake influenced the excretion of both phosphorus and magnesium.

EFFECT OF VITAMIN A DEPLETION ON PLASMA LEVELS OF ASCORBIC ACID AND VITAMIN A IN THE YOUNG DAIRY CALF. H. D. Eaton, C. F. Helmboldt, J. E. Avampato, E. L. Jungherr and K. L. Dolge, *University of Connecticut.*

Nine Guernsey and 9 Holstein male calves, age 105 days and previously raised on a limited-whole milk dry-calf starter regime, were fed a vitamin A-depletion ration. The amount of the depletion ration fed was adjusted to the weight of individual calves at successive 7-day intervals. Plasma vitamin A levels of venous blood samples obtained at similar intervals showed significant decreases whereas plasma ascorbic acid levels in the same samples exhibited no significant trend. Using the data from the 112th day of age until the blood plasma level for each calf decreased to 4 μg. percent and during which time the depletion ration allowance

was readily consumed, regression coefficients of plasma ascorbic acid and plasma vitamin A on age were $-.0029 \pm .0035$ and $-2.3612 \pm .1132$ for the Guernsey calves and $-.0007 \pm .0037$ and $-2.2978 \pm .1462$ for the Holstein calves. Also, since spinal fluid pressures determined at 4-wk. intervals increased to more than 90 mm. before the blood plasma level of vitamin A decreased to 4 μg. percent, it appears that in A-hypovitaminosis uncomplicated by decrease in feed intake plasma levels of ascorbic acid and vitamin A are not related.

THE EFFECT OF SUPPLEMENTING NORMAL AND HIGH PROTEIN CORN WITH LYSINE AND TRYPTOPHAN FOR SWINE. Robert G. Eggert, Merle J. Brinegar and C. R. Anderson, *University of Nebraska.*

Nitrogen balance trials were used to compare the nutritive values of several samples of yellow corn containing different levels of protein. Including corn as the only source of protein, the diets were equalized to 1.3% nitrogen by the addition of corn starch. Corn oil and "Ruffex" were used to equalize fat and fiber levels. Vitamins and minerals were added to all diets. In each comparison, data relating to two samples of corn were obtained from four weanling pigs. Each diet was fed to two of the pigs during one period. The diets were then reversed during a second period. In the first trial, the protein contents of the corn (dry basis, N x 6.25) and values for the percent of apparently absorbed nitrogen retained were: 10.1% protein, average, 31.8 (33.0, 32.7, 29.9 and 31.4); 11.4% protein, average, 30.1 (27.2, 33.5, 31.2 and 28.5). In the second trial, the protein contents of the corn and retention values were: 10.6% protein, average, 37.2 (38.9, 38.7, 32.8 and 38.4); 14.9% protein, average, 27.9 (25.3, 25.9, 32.0 and 28.5). In the third trial, 1.75% DL-lysine-HCl and 0.3% DL-tryptophan were added to both of the diets compared in the second trial. The protein contents of the corn and the retention values were: 10.6% protein, average, 49.8 (53.7, 49.6, 46.5 and 49.6); 14.9% protein, average, 48.1 (42.2, 48.8, 53.0 and 48.3). It appears that the corn having the higher protein content was more deficient in lysine and (or) tryptophan than the corn containing the lower level of protein.

THE UTILIZATION OF CERTAIN CELLULOSIC MATERIALS BY SWINE. T. S. Hamilton and R. M. Forbes, *University of Illinois.*

These studies were conducted to determine the effect of source "crude fiber" on its digestibility and degree of utilizaton by swine and to investigate the advantages of substituting analyses for cellulose and lignin in place of the usual crude fiber estimation. The sources of cellulose investigated were wood flock, ruffex, wheat straw pulp, alfalfa meal, and oat hulls, added to a good basal ration in amounts to give equivalent cellulose values. Determinations of digestibility and metabolizable energy were made, using Duroc Jersey and Poland China barrows weighing initially 125 pounds. Digestibility of cellulose in rations containing about 50% of their cellulose from wood flock, Ruffex, or wheat straw pulp averaged 41, 46, and 68%, respectively. The added cellulose in the same series was apparently digested to the extent of 21, 30, and 92%, respectively. Comparisons of varied fiber sources with wood flock showed the following decreasing order of cellulose digestibility: alfalfa meal, wood flock, wheat straw, and oat hulls. The differences cited above may be associated with lignification of the cellulose and/or chemical variation in the cellulose itself. Cellulose and crude fiber digestibilities exhibited similar trends, and no advantage was seen in routine use for making the more complicated analysis. A modified lignin analysis was developed which gives an average lignin digestibility of 5.1%. Metabolizable energy values, expressed as a percent of the digestible energy, show that the organic acids produced in the digestion of cellulose are highly utilizable by the animal.

THE FEEDING VALUE OF UNDECORTICATED SAFFLOWER MEAL FED TO FATTENING STEERS. W. W. Heinemann, M. E. Ensminger and W. E. Ham, *State College of Washington.*

Three lots of twelve long-yearling steers having an average initial weight of approximately 855 lbs. each were fed for 100 days in fattening trials. The grain ration consisted of a mixture of two-thirds cracked barley and one-third dried molasses-beet pulp. This was fed along with corn silage and alfalfa hay, two to one by weight. Protein was supplied by (1) cull pea meal, (2) cottonseed meal, and (3) undecorticated safflower meal. The average daily gains of the 3 lots were 2.17, 2.07 and 2.09 pounds respectively. In order to supply equivalent amounts of protein it was necessary to feed the supplements in the ratio of 13:8, 8:8 and 17:4. It was necessary to force feed the safflower meal by incorporating it with the grain mix, but no digestive disorders due to feeding safflower meal were observed. Seven, 7 and 5 cattle (pea meal, cottonseed meal, safflower meal) were graded "choice" at the end of the feeding period; the remaining cattle graded "good".

MINIMUM REQUIREMENTS OF GROWING PIGS FOR CAROTENOIDS FROM NATURAL SOURCES. J. F. Hentges, Jr., R. H. Grummer, P. H. Phillips, and G. Bohstedt, *University of Wisconsin.*

Five lots of vitamin A deficient pigs were individually fed equivalent amounts of carotene (25 γ total carotenoids per kg. body wt. daily) as supplied by sun-cured, dehydrated, and pelleted dehydrated alfalfa, yellow corn, and crystalline carotene in cottonseed oil. The alfalfa products differed only by the method of processing. Preliminary studies had shown the minimum requirement of young pigs for purified carotenes in oil to be 25 γ/kg. body wt. daily as measured by blood plasma and liver concentrations of vitamin A, cerebrospinal fluid pressures, night-blindness studies, and rates of gain. Carotenes from pelleted and dehydrated alfalfa were more efficient for restoring blood plasma vitamin A levels than crystalline carotene in cottonseed oil while carotenoids from sun-cured alfalfa and yellow corn were least efficient. All supplements, at the level fed, were adequate for overcoming the vitamin A deficiency; however, the periods of supplementation were longer for sun-cured alfalfa and yellow corn. Although the carotene content of the supplements was determined by total carotenoid analyses, a study of the isomeric forms of carotenes in each feed was conducted for correlation with the biological activity data.

FLUORINE LEVEL OF URINE AS A DIAGNOSTIC MEASURE OF FLUORINE TOXICOSIS IN CATTLE. C. S. Hobbs, C. C. Chamberlain, J. L. West, L. J. Hardin, W. H. MacIntire, and R. P. Moorman, *University of Tennessee.*

Fluorine analysis of the urine of cattle has been suggested as a method of diagnosing fluorosis. A study was made of the fluorine level of the urine of 63 cows that had been fed known levels of fluorine in their rations over periods from six months to three years. Progress results of a series of fluorine analysis of single, one day, and metabolism trial urine voidations show an average of 4.3, 9.4, 14.2, 20, 23, 29.1, 35.2, 34 and 45 ppm. fluorine in urine of cows fed the control rations, and control ration plus the addition of sodium fluorine to give the following amounts as ppm. fluorine to the total dry ration above the amounts in the control ration: 10, 20, 30, 40, 50, 70, 100 and 100 plus defluorophosphate. Preliminary studies indicate metabolism trial urine collections and one-day urine collections to be closely correlated. The analysis for fluorine gives a fair method for the division between cows consuming rations containing less than 20–30 ppm. in dry ration and

those above this level. Single urine voidations from cows consuming rations containing known levels of fluorine vary widely. Present studies show considerable variation in fluorine content of urine samples taken from the same cow at different times or from different cows eating rations containing the same ppm. fluorine in dry ration.

THE EFFECT OF FLUORINE ON COWS AND ON THE DIGESTIBILITY OF NUTRIENTS BY CATTLE. C. S. Hobbs, R. P. Moorman, J. L. West, C. C. Chamberlain, W. H. MacIntire, and L. J. Hardin, *University of Tennessee.*

Eleven lots with three cows per lot have been individually fed rations containing varying levels of fluorine to study the effect of fluorine on weight gains, reproduction, feed consumption and digestibility, teeth, bones and the development symptoms reported in the literature as indications or results of fluorosis. Lot I, control group, received a basal ration of legume hay, ground corn and cottonseed meal, which contained from 5 to 10 ppm. (parts per million) fluorine. Sodium fluoride was added to the concentrate mixtures of lots 2 through 9 to supply the following added levels of fluorine in the total dry ration, respectively, 10, 20, 30, 40, 50, 70, 100 and 100 ppm. plus defluorophos. Teeth of cows fed rations for 40 months containing approximately 15 to 30 ppm. of fluorine added to the control ration show some staining and markings; 30 to 40 ppm. of added fluorine show mottling, caries, wear and erosion; 40 to 50 ppm. of added fluorine show erosion, mottling and pitting. At higher levels of fluorine feeding all the effects are more pronounced. Colored slides are used to provide a permanent picture record of the effect on teeth. Metabolism trials conducted with animals at all levels of feeding indicate that fluorine has little if any effect on the digestibility of the protein, fat, fiber and NFE in these experiments but does result in lower feed consumption at higher levels. Three lots of cows similar to the individually fed groups were put on pasture representing a control pasture and pastures where the forage analysis showed two levels of fluorine.

THE EFFECT OF TERRAMYCIN ON THE GROWTH OF PIGS FED DIFFERENT LEVELS OF PROTEIN. J. A. Hoefer, R. W. Luecke and F. Thorp, Jr., *Michigan State College.*

Eight lots of ten pigs each averaging 25 lbs. in weight were used to study the effect of adding terramycin (5 mg. per lb. of ration) to rations containing different levels of protein (15% and 18%). After the pigs in each lot reached an average weight of 100 lbs. the protein levels were reduced to 12% and 15%. The basal ration included corn, soybean meal, condensed fish solubles, complex mineral mix, vitamins A and D, 3 B vitamins and vitamin B-12. There were four treatments used in duplicate. The treatments and average daily gains for 84 days were as follows: (1) high protein basal, 1.14 lb.; (2) high protein basal plus terramycin, 1.55 lb.; (3) low protein basal, 1.09; (4) low protein basal plus terramycin, 1.57 lb. There were no significant differences between lots in efficiency of feed utilization.

SOME DIFFERENCES IN ADULT AND INFANT RUMEN FLORA OF CATTLE ON PRACTICAL RATIONS. C. N. Huhtanen, R. K. Saunders, L. S. Gall, *National Dairy Research Laboratories, Inc.*

Investigations have been conducted on the rumen flora of 200 calves from three states and 200 adult cattle from eight locations fed practical rations. Different types of organisms were found in the rumen of calves than in mature animals. The 9 organisms characteristic of calves' rumens almost never occur in the rumen of healthy adult cattle eating a balanced practical ration. The 11 adult types start

to occur in calves as early as two months, depending on ration, and become more predominant as the animal grows older. Two types of bacteria occur in ruminants of all ages. The most common types found in the calves' rumens are fast-growing, lactic acid forming bacteria, which produce a low pH and heavy turbidity. One organism, however, uses lactic acid, forming acetic, propionic, butyric and higher acids and gas. The types of organisms isolated most frequently from the adult rumen grow more slowly, often with little turbidity. Usually the pH is not very low, and the acids formed are propionic, butyric, acetic and higher acids, with lactic acid and gas sometimes produced. Two types of bacteria found frequently in animals of all ages are fast-growing organisms. One type is present in almost all ruminants and increases with an increase in grain. This organism produces a very heavy turbidity with a low pH due to lactic acid formation. The other organism is present in the rumen sporadically. It produces moderate turbidity and pH, forming several of the organic acids.

THE EFFECT OF VARIOUS FEEDING SYSTEMS ON GROWTH AND CERTAIN BLOOD CONSTITUENTS OF DAIRY CALVES. N. L. Jacobson, R. S. Allen and M. R. Bell, *Iowa State College.*

Sixty dairy calves were allotted at 4 days of age to six diets varying only in the composition of calf starter. During the first 7 weeks of the 16-week experimental period, the calves were fed a limited amount of whole milk (total milk consumption—3.7 lbs. per lb. initial body weight). Alfalfa hay was fed *ad libitum* and the starter was limited to a maximum of 4 lbs. daily per calf. The growth rate (weight and height at withers) of the group fed a relatively simple concentrate mixture (cracked corn, 40%; crushed oats, 30%; soybean oil meal, 28%; steamed bone meal, 1%; and salt, 1%) was equal to that of the groups fed various starters more "complex" in composition. Since there were no significant differences among groups in the levels of the blood constituents measured, the values for all calves were combined to obtain means. Blood plasma vitamin A levels decreased during the initial 4 weeks, remained constant for 3 weeks and then increased gradually. Plasma carotene values also decreased during the initial 4 weeks but increased sharply thereafter. Blood plasma fat levels were correlated closely with dietary fat intake. Blood glucose values declined steadily during the first 4 weeks and remained relatively constant thereafter. In other experiments (45 calves) in which rumen development was retarded by restricting the animals to various milk diets, similar trends in blood glucose levels were observed. Thus, the suggestion that the decline of glucose levels in young calves results from devlopment of rumen function (McCandless and Dye, Am. Journal Physiol., 162:434. 1950) may require modification.

RESPONSE OF "RUMINATING" DAIRY CALVES TO AUREOMYCIN FEEDING. N. L. Jacobson, J. G. Kaffetzakis and W. R. Murley, *Iowa State College.*

Twenty-six dairy calves (12 Jerseys, 6 Guernseys, 4 Holsteins and 4 Ayrshires) were divided into two groups similar in mean initial weight and in breed and sex distribution. All calves received milk; hay and grain during the period 4 to 116 days of age. One group also received crystalline aureomycin hydrochloride, 80 mg. daily per calf, fed in milk via nipple pail. During the terminal 56 days, the level of milk feeding was reduced to an amount sufficient for administration of the antibiotic. The mean weights for the aureomycin-fed group at 4, 32, 60, 88 and 116 days of age were 68, 94, 134, 181 and 236 lbs., respectively. The corresponding weights for the control group were 67, 85, 118, 154 and 193 lbs. At 116 days of age milk feeding

and crystalline aureomycin hydrochloride supplementation were discontinued and aureomycin in a feeding supplement (Aurofac A, Lederle) was introduced into the concentrate mixture of approximately half the calves in each group. The body weights at 200 days of age of 7 calves fed aureomycin (80–240 mg. per calf daily) continuously from 4 days were approximately 30% above the Ragsdale growth standards. Conversely, the weights of calves which received no aureomycin approximated the Ragsdale values. In most instances there were no apparent adverse effects resulting either from removal of aureomycin from the diet or from initial introduction of aureomycin (80 mg. per calf daily) into the ration of calves at 116 days of age.

MOLYBDENUM TOXICITY IN THE NUTRITION OF THE RAT. THE EFFECT OF VARYING LEVELS OF MOLYBDENUM UPON FERTILITY, GESTATION AND LACTATION. Max A. Jeter and George K. Davis, *University of Florida.*

There was a sexual difference in the response of males and females to levels of molybdenum of 20, 80 and 140 parts per million in diets containing 5 parts per million of copper. There seemed to be no apparent damage to gestation in rats fed these levels of molybdenum, and it was also apparent from observations on weight and size of litter that the toxic levels of molybdenum did not pass through the placenta. In males, a high proportion of those receiving added molybdenum became sterile. The minimum amount of molybdenum which caused a 75 percent sterility appeared to lie between 20 and 80 parts per million in the diet containing 5 parts per million of copper. Limited histological studies indicated varying degrees of seminiferous tubule degeneration in the sterile rats. When the level of molybdenum was increased to 700 parts per million, the females developed irregular estrus after receiving the ration for 10 days. Using various criteria for lactation performance, it was observed that females on molybdenum levels of 20, 80, and 140 parts per million gave poorer lactation performance although feed intake appeared to be equivalent to that of the rats on the control rations. Copper concentrations in the maternal livers indicated that there was some increase in copper concentration at the 80 parts per million of molybdenum level, whereas, there appeared to be some decrease at the 140 parts per million molybdenum concentration at the end of a 21-day lactation period.

EFFECT OF AUREOMYCIN ON GROWING AND FATTENING LAMBS. R. M. Jordan and T. Donald Bell, *South Dakota and Kansas State College.*

The effects of small amounts of aureomycin (5 to 15 mg. daily) on the rate of growth of suckling and fattening lambs were studied. Ten suckling lambs were drenched with 5 mg. of aureomycin daily for six weeks. During this time they gained an average of .64 lb. daily as compared to ten control lambs that gained .54 lb. daily. Four other lambs were drenched with 15 mg. and made an average daily gain of .59 lb. All the lambs receiving aureomycin were normal in every respect. Two trials were conducted of fattening lambs full fed a standard corn-alfalfa ration and supplemented with 6–12 mg. of aureomycin per lamb daily. During the first preliminary trial, 21 lambs fed 6 mg. of aureomycin gained .49 lb. per lamb daily as compared to .39 lb. per lamb daily for the controls. The treated lambs required 22 percent less concentrates per 100 lbs. of gain. In a second trial, now being conducted, 16 lambs receiving 10.8 mg. of aureomycin per lamb daily gained .40 lb. per lamb daily as compared to the controls which gained .36 lb. per lamb daily. The treated lambs required 20 percent less feed. The final results of this second trial will be presented along with the results from a third trial that has just started.

THE EFFECT OF TRACE MINERALS AND METHIONINE UPON THE UTILIZATION OF PROTEIN BY SHEEP. Earle W. Klosterman, D. W. Bolin, and W. E. Dinusson, *North Dakota Agricultural College.*

A ration of wheat straw, cane molasses, field peas, cerelose, di-calcium phosphate and salt was fed to growing ewe lambs. The addition of cobalt significantly improved the biological value of the protein in this ration. The cobalt had no apparent effect on digestibility of protein. The difference in biological value between the control and cobalt rations became greater as the experiment progressed. The biological values for three periods for the control and cobalt rations were: 44.7, 45.2; 44.7, 49.6; and 50.3, 58.5 respectively. The addition of 0.2 percent DL methionine brought about no improvement in either the control or cobalt ration. In a second experiment yearling ewes were fed a ration of wheat straw, cane molasses, yellow corn, urea, di-calcium phosphate and salt. The addition of cobalt or a complex mineral supplement brought about no improvement in digestibility or utilization of the protein in this ration. The average biological values for four periods for the control, cobalt and complex mineral rations were 65.2, 64.7, and 64.4 respectively. The addition of 0.2 percent DL methionine was also of no benefit in this experiment. The difference in the effect of cobalt obtained between the two experiments may have been due to the difference in rations or the age of the ewes fed.

THE EFFECT OF MOLYBDENUM ON THE METABOLISM OF COPPER IN SWINE AND RATS. Roman Kulwich, Sam L. Hansard, C. L. Comar and George K. Davis, *Tennessee and Florida Agricultural Experiment Stations.*

Feeding a 0.1% dietary level of moybdenum as sodium molybdate to rats and swine resulted in striking increases in tissue copper concentration. After albino rats had received a natural ration with this high level of molybdenum for 14 weeks, analyses showed about a threefold increase in liver copper concentration, while after 25 weeks of this high dietary molybdenum level in purified ration, liver copper values were increased about 6–300 times the levels found in the controls. A study with radioactive copper confirmed the increased copper retention of rats receiving a high dietary level of molybdenum. Feeding the 0.1% level of molybdenum in a natural ration to Hampshire swine resulted in about a fivefold increase in liver copper concentration after seven months. While a considerable retardation of growth resulted in all rats fed 0.1% molybdenum in the ration, this level caused no appreciable growth retardation in swine. The addition to the ration of 0.02% copper as the sulfate had no modifying effect upon the growth rate of rats or swine receiving 0.1% molybdenum. No gross pathology attributable to the high molybdenum intake was observed in rats or swine. Subsequent studies using radioactive copper indicated that short-term molybdenum supplementation by means of daily drenching for eight days resulted in increased retention of labeled copper by either weanling or mature albino rats. The data support the hypothesis that on a high molybdenum intake copper may be accumulated in a physiologically ineffective form.

ADEQUACY OF BROOD SOW RATIONS IN DRY LOT. J. F. Lasley, L. F. Tribble and A. G. Hogan, *University of Missouri.*

Three separate feeding trials involving 44 gilts have been conducted in dry lot during the past 3 years for the purpose of studying nutrient requirements of swine

during gestation and lactation. In trial I, 6 gilts received ration 347 (corn 70, tankage 5, soybean meal 20, alfalfa meal 2.5, cod liver oil 0.5 and complex minerals 2.0). A second group of 3 gilts received ration 348 (347+10 mcg of vitamin B_{12} per pound of feed). The percentages of pigs weaned and average litter weight at 56 days for ration 347 were: 86.7% and 201.6 lbs. and for ration 348: 100% and 289.6 lbs. In trial II, 5 gilts received ration 353 (corn 70.5, soybean meal 25.0, alfalfa meal 2.5, complex minerals 2.0 and riboflavin, calcium pantothenate and nicotinic acid. A second group of 5 gilts received ration 354 (353+10 mcg. of B_{12} per pound of feed) and a third group of 5 gilts ration 353+green, cut rye. The percentages of pigs weaned and total litter weight at 56 days for ration 353 were: 91.1% and 222.6 lbs., ration 354: 97.5% and 294.1 lbs. and ration 353+rye: 100% and 354.4 lbs. In trial III, one group of 10 gilts received ration 353 and a second group of 10 received ration 354. The percentages of pigs weaned and total litter weight at 56 days for ration 353 were: 72.5% and 183.5 lbs. and for ration 354: 83.5% and 206.6 lbs.

THE EFFECT OF EXCESS CALCIUM WITH BORDERLINE AND DEFICIENT PHOSPHORUS IN THE RATIONS OF STEER CALVES. James K. Lewis, William H. Burkitt, and Fred S. Willson, *Montana Agricultural Experiment Station.*

An experiment was conducted involving 38 steer calves individually fed for 120 days on rations containing adequate, borderline, or deficient phosphorus with normal or excess calcium. Rations were supplemented with iodine, cobalt, copper, manganese, and vitamins A and D. Feed consumed per 100 pounds body weight and rate of gain were reduced by borderline or deficient phosphorus intakes. Excess calcium added to a ration of borderline phosphorus content further reduced both feed consumption and rate of gain. However, when excess calcium was added to a deficient phosphorus ration, feed consumption was decreased, but rate of gain was not affected. The phosphorus plasma levels were related in a general way to the phosphorus intake, but the calcium plasma level showed a characteristic fluctuation which was unaffected by treatments or by phosphorus plasma levels. The carotene plasma levels were inversely proportional to the phosphorus plasma levels and to the phosphorus intake and appeared to be directly proportional to the calcium intake. The symptoms of phosphorus deficiency in the order of their appearance were: Impaired feed utilization, reduced rate of gain, poor feed consumption, depraved appetite, emaciation, rough hair coat, stiffness of the hind legs, enlargement of the knees and hocks, and alteration of body conformation. Depraved appetite was present in all lots and may have been due in part to the finely-divided state in which the ration was fed. Steers wintered on inadequate intakes of phosphorus with either normal or excess calcium made excellent gains on summer pasture and grain supplemented with phosphorus.

"THE EFFECT OF NUTRITION ON WOOL PIGMENTATION". Merle R. Light, Earle W. Klosterman, M. L. Buchanan, and D. W. Bolin, *North Dakota Agricultural College.*

In previous experiments on the conversion of carotene to vitamin A in sheep at this station, several sheep were observed to have an excessive amount of melanin in their skin during the latter stages of vitamin A deficiency. One sheep of Hampshire ancestry grew wool showing a wool color reversal and the banded effect similar to that reported for a diet too high in molybdenum. Further studies of

the above problem with lambs of Hampshire and Delaine Merino ancestry and lambs that were heterozygous for black showed that only lambs of Hampshire origin showed a color reversal when given a diet which was deficient in vitamin A and vitamin D. Lambs which showed a color reversal after prolonged deficient diets were treated with either water soluble injectable vitamin A or a vitamin A+D concentrate given by a stomach tube. Lambs given vitamin A and D treatment responded by reverting to their original wool color. No response was obtained from jugular injections of vitamin A.

FECAL AND URINARY EXCRETION BY SHEEP OF SEVERAL B VITAMINS ON HAY AND SYNTHETIC DIETS. Ivan L. Lindahl, L. A. Struglia and P. B. Pearson, *U. S. Dept. of Agriculture.*

One group of sheep was fed a mixed hay diet containing 13.6% protein and 26.5% fiber while a second group was fed purified diets containing 6.8% fiber and three different levels of protein. The low protein diet contained 3.6% protein; the second diet contained 12.6% protein (supplement of 10% casein); while the third diet contained the equivalent of 15.2% of protein (10% casein plus 1% urea). The feeds, feces and urine were assayed by standard microbiological procedures for riboflavin, niacin, pantothenic acid and vitamin B_{12}. The amounts of the vitamins excreted by the sheep fed the purified diet plus casein were not significantly influenced by the addition of urea. The excretion of niacin was significantly higher on the purified diet containing casein than on the low protein diet indicating that tryptophan is converted to niacin by sheep. After deducting the amount of B_{12} ingested, the sheep on the mixed hay diet excreted 3.7 times as much B_{12} as did the sheep on the purified diet. This presumably indicates greater microbial synthesis of vitamin B_{12} on the mixed hay diet than on the purified diet. The amounts of riboflavin, niacin and pantothenic acid excreted by the sheep on the mixed hay diet were less than the amounts ingested, however the mixed hay diet provided several times the estimated physiological requirements for these vitamins. The result is in accord with previous observations that when large amounts of these vitamins are ingested by sheep only relatively small amounts are recovered in the urine and feces.

RELATIONSHIP OF PANTOTHENIC ACID AND VITAMIN B_{12} IN THE GROWING PIG. R. W. Luecke, J. A. Hoefer and F. Thorp, Jr., *Michigan State College.*

Previous work seemed to indicate a possible relationship between pantothenic acid and vitamin B_{12}. In the present experiment two basal rations were used: Ration A, containing corn, 73%; soybean meal, 22%; Menhaden fish solubles, 2%; mineral mixture, 3%. Ration B contained corn, 83%; soybean meal, 12; Menhaden fish solubles, 2%; mineral mixture, 3%. Both rations contained added amounts of vitamins A and D, niacin and riboflavin. The protein contents of rations A and B were 18% and 15% respectively. Seventy-two weanling pigs were divided equally into 8 lots of 9 pigs each. The average initial weight of all lots was approximately 21 lbs. The following experimental treatments were used: Lot 1, ration A; lot 2, A+B_{12} @ 25 μg./lb.; lot 3, A+calcium pantothenate @ 4 mg./lb.; lot 4, A+B_{12} +calcium pantothenate; lot 5, ration B; lot 6, B+B_{12} @ 25 μg./lb.; lot 7, B+ calcium pantothenate @ 4 mg./lb.; lot 8, B+B^{12}+calcium pantothenate. The average daily gains and feed efficiency, in parentheses, at the end of eight experimental weeks are as follows: lot 1, 0.36 (4.25); lot 2, 0.46 (3.67); lot 3, 0.66 (3.05); lot 4, 0.61 (3.09); lot 5, 0.81 (2.49); lot 6, 0.72 (2.76); lot 7, 0.84 (2.58); lot 8, 1.06 (2.49).

ANTIBIOTICS IN RATION OF HOGS—EFFECT OF WITHDRAWAL AND LONG TERM FEEDING, LEVELS AND COMPARISON OF ANTIBIOTICS INCLUDING ANTI-FUNGAL TYPE. H. G. Luther and J. H. Brown, *Chas. Pfizer & Co., Inc. and Arenel Farms.*

Six successive controlled tests have been run with antibiotics in the ration of hogs to observe the effect of long time antibiotics feeding practices on the growth stimulating effects of antibiotics. In these tests terramycin was included in the gestation, lactation and creep rations at a level of 8 grams per ton. The results show that under the controlled dry lot feeding conditions the growth stimulation from terramycin supplementation was essentially unchanged, giving 20 to 45% increase in growth at eight weeks, 8 to 15% at market weight. An improvement in the control groups was noted. Similar results were observed with a new stable form of penicillin. Under test conditions at one farm optimum response has been obtained several times at levels 4 parts per million of terramycin. Withdrawal of terramycin from the ration at periods as early as six weeks has given good results, however, level and time of supplementation required undoubtedly vary with field conditions. Rimocidin, a new antibiotic effective against yeast and mold, but ineffective against bacteria gave a 51% increase in rate of growth at eight weeks, an observation which complicated some prevailing theories on mode of action of antibiotics in promoting increased rate of growth.

SOWS MILK SUBSTITUTE FOR PRACTICAL FEEDING OF BABY PIGS—EFFECTS OF VARIOUS LEVELS OF ANTIBIOTICS, FAT, SOLID, PROTEIN, ETC. H. G. Luther and J. H. Brown, *Chas. Pfizer & Co., Inc. and Arenel Farms.*

Results are presented on the feeding of baby pigs on a "semi-synthetic" milk of practical composition under laboratory, scientific farm and practical farm conditions. Results on the rearing of over 1000 baby pigs show the feasibility of this type feeding. Data are presented on the effect of inclusion of various antibiotics, combinations of antibiotics, levels of terramycin, levels of fat, solid and specific protein as fish solubles, etc. Levels of 50 to 100 parts per million (dry basis) are desirable. Fat level seems to have little importance. The rate of gain is proportional to solids fed, but the feed efficiency is inversely proportional to the level of solids fed. The inclusion of fish solubles improved the performance of the semi-synthetic milk markedly. Information is presented on various management methods, an extremely important factor determining the results obtained with synthetic milk feeding. Results of adaptation to commercial hog raising are presented. Colostrum feeding is required in most instances for 24 to 48 hours, considerable variation occurring between litters. Several colostrum substitutes have been tried without success.

THE VALUE OF AMMONIATED INDUSTRIAL BY-PRODUCTS IN THE RATIONS OF DAIRY HEIFERS AND COWS. N. D. Magruder, C. B. Knodt, P. S. Williams, *Pennsylvania Agricultural Experiment Station.*

Three experimental feeding trials have been completed to study the value of available by-products (Commercial Solvents Corporation) upon the milk production and body weights of Holstein milk cows, and the growth rates of Holstein heifers. The five ammoniated molasses samples (6.25 x N=13.2% to 36.8%) were added at a 10% level to a basic grain mixture to equal an average total content of 16% with variations in the soybean oil meal and oats contents. These were compared with a control (10% cane molasses) and a urea ration of the same protein level. Data from the milking cow trials showed no statistical significant difference in

treatments for milk production or body weights. Four dairy heifers were fed ammoniated Masonex (28.7% protein equivalent) as 10% of the total ration as compared to four heifers fed the control ration. Average mean gains were 127.75 lbs. for the control group compared with 124.75 lbs. for the Masonex fed group for the 90 days feeding trials. One heifer was fed 60% of an ammoniated molasses product before refusal; ill effects being negligible. Ration samples were stored and sampled to determine any change in nitrogen content. At 180 days there were no decreases. Preliminary studies on percent of digestibility (Chromogen method), nitrogen and ammonia nitrogen content of urine, feces and milk fail to reveal any differences. The results obtained by the use of analysis of covariance to eliminate the effect of differences in beginning weights were comparable with the results obtained by the analysis of variance.

MOLASSES AS A REPLACEMENT FOR GRAIN IN THE RATIONS OF GROWING HEIFERS AND MILKING COWS. R. E. Mather and C. B. Bender, *New Jersey Agricultural Experiment Station.*

To study the use of larger amounts of molasses in dairy rations, trials with growing heifers and milking cows were set up. A single reversal trial with two 4-week periods and 18 Guernsey and Holstein heifers showed no significant difference in rate of gain when molasses was fed ad libitum from individual self-feeders replaced 4 lb. daily of grain. Molasses consumption ranged from 6.1 to 20.6 lb. per day per heifer. With ten milking cows in a double reversal trial of three 2-week periods each preceded by one-week transition, molasses T. D. N. replaced one half of the grain T. D. N. and brought about highly significant reductions in daily milk production (3.08 lb.), butterfat test (0.35 percent), and 4-percent fat-corrected milk (4.83 lb.). Weight changes did not differ significantly. The reduction in production may be attributable to an intake of protein borderline with regard to requirements, and its influence on rumen microorganisms. A third similar group received molasses ad libitum from individual self-feeders in addition to the full grain ration. The slight increase in production was not statistically significant. Molasses consumption reached a maximum of 12.2 lb. per day for one cow.

THE EFFECT OF RATION ON THE B_{12}, RIBOFLAVIN, AND NIACIN CONCENTRATION OF THE BLOOD AND MILK OF SHEEP. M. Moinuddin, A. L. Pope, P. H. Phillips, and G. Bohstedt, *University of Wisconsin.*

Forty grade Hampshire ewes were divided into four groups after breeding in 1949 and fed the following rations through gestation and lactation: Basal (fair alfalfa hay, oat straw, corn, and iodized salt); Basal+minerals (cobalt, manganese, copper, iron, calcium, and phosphorus); Basal+protein (soybean oil meal); and Basal+protein+minerals. The blood and milk of the ewes and the blood of the lambs were analyzed periodically for riboflavin and niacin content. No significant differences between lots were observed. The colostrum was considerably higher in riboflavin than normal milk while the reverse was true in the case of niacin. At birth the lambs had a high blood level of riboflavin that gradually decreased. The niacin blood level of the lambs remained rather constant. The transfer of vitamins from dam to offspring and the effect of the vitamin concentration of the milk on the blood concentration of the lamb were observed. The following year the ewes were divided into the following four groups: Basal; Basal+cobalt; Basal+calcium and phosphorus; and Basal+cobalt+calcium and phosphorus. The purpose of this study was to determine the effect of mineral supplementation on the vitamin B_{12} concentration of the blood and milk of ewes and in the blood of their lambs. A significant increase was found in the blood and milk of ewes and lambs receiving

cobalt either alone or in combination with calcium and phosphorus. Colostrum was much higher in vitamin B_{12} than normal milk and the lambs' blood level increased from birth to 8 weeks of age.

EFFECT OF APF (ANTIBIOTIC FEED SUPPLEMENT) SUPPLEMENTATION DURING THE FIRST TWO WEEKS OF LIFE ON THE WELL-BEING AND GROWTH OF DAIRY HEIFERS. S. H. Morrison and J. F. Deal, *University of Georgia.*

Eighteen purebred heifer calves consisting of two groups of 9 each (5 Jersey, 3 Holstein and 1 Guernsey) were raised by the minimum milk method, weaning calves at twelve weeks of age. One group served as control; the other group received antibiotic feed supplement (Lederle) at the rate of 1% of the dry matter of the milk for two weeks after removal from the dam (3rd day). Starting at 18 days of age, all animals had free access to U. S. No. 2 Lespedeza hay. Also, starting at this same time, all animals were fed calf meal according to appetite up to a maximum of 2½ to 3 pounds daily for Jerseys and Guernseys, and 3½ to 4 pounds for Holsteins. No differences were observed in incidence of scouring, general health, gain in weight to 12 weeks, milk consumption, hay consumption or grain consumption when measured by means of Student's "t" test for significance. Field trials are being carried out at the present time with the feeding of this material under practical farm conditions for longer periods of time.

EFFECT OF VITAMIN A ON ECONOMY OF GAIN IN SWINE RECEIVING THIOURACIL. M. E. Muhrer and Zane Palmer, *University of Missouri.*

The increased economy of gain in swine fed goitrogenic compounds is of short duration as growth is retarded after 4 weeks of supplementation. Since thyroxin is associated with carotene metabolism it seemed possible that the retarded growth rate in the thiouracil-fed swine might be due to a vitamin A deficiency. In order to test this possibility five separate feeding trials were run using a total of 58 pigs divided into three groups. One group received the basal ration, one group received thiouracil (.1% of ration) and the third group received thiouracil plus 400 I. U. of vitamin A per pound of feed. The animals that received the vitamin A supplement made faster and more economical gains than either of the other groups for the first 3 weeks of the trials. During this time the animals on the basal ration required 468 lbs. of feed per 100 lbs. of gain. The addition of thiouracil decreased this to 371 lbs. and vitamin A further decreased the requirement to 319 lbs. of feed per 100 lbs. of gain. After the fourth week the rate and economy of gain decreased rapidly in both groups receiving thiouracil but decreased more rapidly in the vitamin A supplemented group. These data indicate that the addition of vitamin A to a ration containing thiouracil for swine increases both the rate and economy of gain for a short time. However, vitamin A is not the only factor in the growth retarding effect of thiouracil.

THE EFFECT OF AUREOMYCIN ON FEED NUTRIENT UTILIZATION BY YOUNG DAIRY CALVES. W. R. Murley, R. S. Allen and N. L. Jacobson, *Iowa State College.*

Ten male Holstein calves were restricted, during the period from 4 to 60 days of age, to a diet of reconstituted skimmilk (1 part non-fat dry milk solids: 4 parts water) supplemented with vitamins A and D. The calves were muzzled except at feeding time. To half the calves crystalline aureomycin hydrochloride, 80 mg. daily per calf, was fed in the milk via nipple pail. Three successive 24-hour samples of

urine and feces were obtained from each calf at 2, at 5 and at 8 weeks of age. Analyses of the urine for reducing sugars and nitrogen and of the feces for dry matter, reducing sugars, nitrogen, ether extract and ash revealed no differences attributable to aureomycin supplementation. Once during each 3-day collection period, blood samples were taken at feeding time and 2, 4, 6, 8 and 10 hours post-prandially and were analyzed for reducing sugars. Although the mean blood reducing sugar levels rose slightly more rapidly and exhibited greater increases in samples from calves fed aureomycin than in those from the controls, the differences were not statistically significant. The growth-stimulating effect of aureomycin did not appear to be so great in this dietary regime as that observed with similar calves fed hay and grain in addition to the milk.

SALT AS A MEANS OF REGULATING CONSUMPTION OF COTTONSEED MEAL BY BEEF CATTLE. A. B. Nelson, R. W. MacVicar, W. J. Van Arsdell and A. E. Darlow, *Oklahoma A & M College.*

Thirty-seven grade Hereford cows were used to study the effect of self-feeding a mixture of salt and cottonseed meal to pregnant beef cows wintered on dry native grass. The cows grazed native grass pasture and during the winter season were hand-fed cottonseed cake or self-fed a salt-cottonseed meal mixture. Cows hand-fed an average of 2.6 pounds of cottonseed cake per day gained an average of five pounds per head from the beginning of the winter feeding period until just before calving. Cows self-fed 2.7 pounds of cottonseed meal daily in a salt-cottonseed meal mixture, which contained an average of 33 percent salt, lost an average of fifteen pounds. The average birth weights of calves were 76 and 67 pounds in the groups of cows fed cottonseed cake and salt-cottonseed meal mixture, respectively. The cows in both lots previously produced calves which weighed 73 pounds at birth. Plasma sodium and potassium levels of the cows were essentially the same in both groups throughout the experimental period. A slight elevation (averaging less than ten percent) was noted in the plasma chloride of the cows receiving the salt cottonseed meal supplement. No differences were noted in the sodium, potassium, or chloride content of the plasma of calves suckling each group of cows. Milk samples were collected at intervals during early lactation and no differences in these same constituents were found.

THE LONG-TIME EFFECT OF FEEDING AUREOMYCIN TO FATTENING BEEF CATTLE, WITH BACTERIOLOGICAL DATA. A. L. Neumann, R. R. Snapp, L. S. Gall, *University of Illinois.*

No benefit was obtained when aureomycin, either in crystalline form or as a crude concentrate containing residual vitamin B_{12} (Aureofac), was added to a basal fattening ration of corn silage, ground yellow corn, linseed meal, and salt, fed to 18 yearling beef heifers for 150 days. Neither did the low level fed (2 mg. aureomycin per pound air dry feed) bring about any extremely unfavorable physiological disturbances. Severe reduction in appetite was shown for a few days but partial recovery was made, and for the entire 150 days, the heifers receiving aureomycin voluntarily consumed a daily ration equal to approximately 2% of their body weight. Diarrhea was never present and no signs of abnormal paunch distension were seen. Water intake was erratic in the lots receiving aureomycin. Daily gains of 2.06, 1.94 and 1.96 pounds were made during the first 75 days while the heifers were equally trio-fed the basal ration, basal ration plus crystalline aureomycin. and the basal ration plus aureomycin crude concentrate, respectively. At the end of the 150 day trial, after the heifers were individually *ad libitum* fed the above

rations for the second 75 days, daily gains of 1.82, 1.74 and 1.81 pounds had been made. These differences in daily gain were not statistically significant. Voluntary feed intake in the control lot receiving no antibiotic was slightly greater after ad libitum feeding was begun. The equality of gains made by the control lot and the lot receiving vitamin B_{12} (at least 3.6 mcg. vitamin B_{12} per pound air dry feed) suggests that the aureomycin destroyed or reduced the vitamin B_{12} synthesizing microorganisms. At the conclusion of the 150 day feeding period, the control lot was fed the ration formerly fed to the crystalline aureomycin lot and they went off feed during the second day on this ration. Feed efficiency figures for the three lots were not statistically significant, indicating that adequate numbers of microorganisms were present in all lots. Bacteriological studies of fresh rumen material were made after 30 days on test. These studies consisted of gram stains to observe morphological types of organisms present and an anaerobic cultural series to study the physiological types of organisms present. Total counts were about the same in all lots, but the types of organisms found in the heifers receiving aureomycin were much less diverse, suggesting that the normal bacterial flora had been disturbed.

RESPONSE OF BABY PIGS TO ANTIBIOTICS. P. R. Noland, E. L. Stephenson, T. S. Nelson, and D. L. Tucker, *University of Arkansas.*

Two-day-old baby pigs were fed an alpha-protein synthetic milk diet for a 3 week period. All pigs used were litter mates. Two pigs were subjected to each of the following treatments: unsupplemented control, control plus penicillin, control plus aureomycin, and control plus terramycin. The crude supplements were fed to supply 5 mg. of the pure antibiotic per pound of dry matter. The aureomycin and terramycin supplements increased both rate and efficiency of gains. All of the antibiotic supplements reduced the fecal-anaerobic bacteria counts by about the same extent, but the pigs failed to respond to the penicillin supplement to the same extent as they did to the aureomycin and terramycin products.

THE DEPOSITION IN THE DEVELOPING FETUS OF LABELED CALCIUM ADMINISTERED TO PREGNANT HEIFERS. M. P. Plumlee, Sam L. Hansard, C. L. Comar and C. S. Hobbs, *Tennessee Agricultural Experiment Station.*

Three pregnant heifers in the third month, three in the sixth month, one in the seventh month, and one in the eighth month of gestation were dosed orally with labeled calcium and sacrificed seven days later. One intravenously dosed heifer in the eighth month of gestation was sacrificed at each of these time intervals after dosing; 10 minutes, 8 hours, 30 hours, and 7 days. After oral administration the accumulation in soft tissues of labeled calcium was similar in the dam and the fetus. Fetus age did not appear to influence either blood level in the dam, or soft tissue accumulation in either dam or fetus. However, the fetus bones always showed a higher concentration than those of the dam; this varied with the age of the fetus and between bones and parts of the same bone. Turnover rate was also greater in the fetal bones. The relative uptake by the soft tissues of fetus and dam after intravenous administration was dependent upon the attainment of equilibrium of the administered Ca between the blood of the fetus and the dam. This was only partially true with the bones. The concentration of Ca^{45} in blood of the dam was approximately 20, 2, 1.5, and 1 times that of the fetus at 10 minutes, 8 hours, 30 hours, and 7 days after injection, respectively. Whereas, the concentration in the metatarsal shaft of the fetus was approximately 1.0, 1.5, and 5.6 times that of the dam at 10 minutes, 8 hours, and 30 hours after injection, respectively.

UTILIZATION OF DL-TRYPTOPHAN IN THE BABY PIG. Elwood Reber, C. K. Whitehair and Robert MacVicar. *Oklahoma A. & M. College.*

The utilization of DL-tryptophan by swine has been studied by nitrogen balance technique using the baby pig. Five littermate Chester White pigs were obtained at two days of age and fed a typical "synthetic milk" ration. After adjustment, they were gradually shifted to a ration containing: commercial zein, 17.5; gelatin, 17.5; lard, 41.5; lactose, 19.0; mixed salts, 5; DL-lysine, 1.0; DL-methionine, 0.2. During a six-day period on this ration the pigs exhibited a depressed appetite, lost weight, but maintained nitrogen equilibrium, the average retention being —0.02 gm. of N per day. The animals were then fed equal quantities of this ration supplemented with 0.1% DL-tryptophan or 0.05% L-tryptophan for two successive eight-day collection periods. Animals receiving DL-tryptophan had a better appetite, and made somewhat greater weight gains. Nitrogen retention was essentially the same for both types of supplements, averaging +1.1 gm. per day for the DL-form and +1.0 for the L-isomer. A second series of two trials followed using 0.2% DL-tryptophan and 0.1% L-tryptophan. Again, the animals receiving the DL-form exhibited an improved appetite. No difference in weight gains was noted, however, and the nitrogen retention was again nearly the same for both groups, +1.69 grams of N per day and +1.84 gm. for DL- and L-tryptophan, respectively. On the basis of these findings it is concluded that little if any use was made of the D-isomer of tryptophan in promoting nitrogen retention on a diet deficient in this amino acid.

EFFECT OF SELF-FEEDING SALT-COTTONSEED MEAL MIXTURES TO BEEF BREEDING COWS. J. K. Riggs, R. W. Colby and H. A. Smith, *Texas Agricultural Experiment Station.*

Data on consumption of water and of salt and cottonseed meal from mixtures self-fed to breeding cows fed levels of hay ranging from sub-maintenance to full feed are presented. Data are also presented on chloride content of the blood, colostrum, and normal milk, and of the urine and feces, as well as the influence of high salt intake upon digestibility of nutrients. Salt limited intake of concentrates from self-fed mixtures with no ill effects when cows were gradually adjusted to high salt intake and had free access to water. Chlorides in the blood, colostrum, and normal milk showed little difference between cows fed high salt intake and those fed control rations. Cows fed high salt allowance consumed considerably more water and excreted a much greater volume of urine than cows receiving only a normal salt allowance. Total chloride excretion of the high-salt cows was 11.5 times that of the controls, 98.3 percent of which was excreted in the urine. Histological studies showed no kidney damage. Data from a digestion trial indicate a beneficial effect of high salt intake upon digestibility of nutrients, particularly protein, crude fiber and nitrogen-free extract with a less significant effect on ether extract digestion. High salt intake appeared to have no detrimental effect upon reproductive performance of the cows.

VITAMIN CONCENTRATES AND DISTILLERS' SOLUBLES AS SOURCES OF B VITAMINS FOR PIGS. W. L. Robison, *Ohio Agricultural Experiment Station.*

Pigs fed a B vitamin concentrate and others fed dried distillers' grain solubles with a ration of corn, soybean oil meal, ground alfalfa, minerals, irradiated yeast, and a B_{12} and antibiotic, aureomycin, supplement in two dry lot experiments gained 1.66 and 1.72 pounds daily and required 362.9 and 350.3 pounds of feed per 100

pounds of gain, respectively. The concentrate supplied 3 mg. riboflavin, 6 mg. calcium pantothenate, 13.5 mg. niacin, and 15 mg. choline chloride per pound of feed. Five percent of dried distillers' solubles were fed. Before and after the pigs averaged approximately 120 pounds in weight those having the B vitamin concentrate gained 100.0 and 92.7 percent as rapidly and required 99.1 and 106.0 percent as much feed per unit of gain, respectively, as those having the dried distillers' solubles. In the first eight weeks of a third experiment pigs fed a concentrate, which in addition to the B vitamins mentioned supplied folic acid and pyridoxine at the rates of .09 and .75 mg. per pound of feed gained 3.6 percent faster but required 6.3 percent more feed per unit of gain than pigs fed dried distillers' solubles. Although a B vitamin concentrate with a ration of the type used resulted in good performance, the data provided further evidence, unless one was inadequate, that dried distillers' grain solubles contains some nutritional factor or factors other than those included in the concentrate.

ANTIBIOTIC AND METHIONINE SUPPLEMENTATION OF THREE VARIETIES OF PEAS IN RATIONS FOR FATTENING-GROWING PIGS. Burch H. Schneider, E. E. Goodwin, and M. E. Ensminger, *The State College of Washington.*

To utilize peas as a protein supplement, it is necessary to identify their shortcomings and make suitable additions. Consideration should be given to supplementation with amino acids, vitamins, and antibiotics. In this study, 84 pigs were used with 12 experimental treatments. The basal ration consisted of barley, peas, alfalfa meal, iodized salt, bone meal, ground limestone, and vitamin B_{12}. Methionine and streptomycin were added singly and together. Also, three varieties of peas were investigated: yellow or "First and Best", green or "Alaska", and black or "Austrian", which vary in market values and differ in yields and other agronomic qualities. With all varieties the most rapid gains were obtained when streptomycin was added at a level of 30 gm. per ton. The pounds of gain per pig daily for the basal alone, basal plus methionine, basal plus streptomycin, and basal plus both methionine and streptomycin, respectively, are as follows: 1.42, 1.39, 1.57, and 1.43. The pounds of feed per 100 pounds of gain for the same additions, respectively, were as follows: 418, 420, 401, and 421. The methionine level (0.05 percent) was perhaps not high enough to be effective. The pounds of gain daily and the pounds of feed per 100 pounds of gain, respectively, for varieties were as follows: yellow 1.40, 420; green 1.49, 405; and black 1.42, 420.

THE EFFECT OF FEEDING ANTIBIOTICS ON EXPERIMENTALLY PRODUCED SWINE ERYSIPELAS. Burch H. Schneider, G. R. Spencer, and M. E. Ensminger, *The State College of Washington.*

Thirty-two weanling pigs were divided into four lots of eight pigs each and fed the same basal ration. Lot 3 received 15 mg. of penicillin and lot 4 15 mg. of terramycin per pound of feed. After two weeks, lots 2, 3, and 4 were exposed to a mixed culture of three strains of *Erysipelothrix rhusiopathiae* by a dermal scratch method. Twenty-four hours later the dermal scratches were surrounded by areas of reddening and edema 2 cm. wide and 15 mm. thick. The pigs were slightly stiff and depressed. Elevations in temperatures were noticed after 24 hours, and increased to the third day—many temperatures exceeding 106 degrees Fahrenheit. At two-week intervals thereafter, two pigs from each lot were sacrificed for post mortem examinations. Heart valve lesions, arthritis, lymphoid hyperplasia and inflammation, and lameness were noticed in different pigs, but there were no significant differences among the three groups of exposed pigs. There was no advantage noted from the addition of antibiotics to the ration. The removal of pigs for the post mortem

examinations obscured differences in weight gains. As the antibiotics were given by mouth, they would have a much better chance of inhibiting infection which also entered by way of the alimentary tract. Experimental erysipelas has not been produced *per os*. Higher levels of antibiotics might produce blood levels more inhibitory to the organism.

THE EFFECTS OF NUTRITIONAL DIFFERENCES ON PREGNANT KARAKUL EWES AND THEIR PRODUCTION OF LAMBSKIN FUR. V. L. Simmons, T. S. Yao and R. G. Schott, *U. S. Dept. of Agriculture*.

A three year study was conducted to determine the effects of feeding Karakul ewes at high and low levels of nutrition during pregnancy on various factors of lambskin fur production. Each year approximately 86 ewes were divided into two lots balanced for age, type of breeding, and normal weight, and were handled similarly except that the high level ewes received an average of 2.20 T.D.N. (total digestible nutrients) and the low level ewes an average of 1.52 T.D.N. per head daily during pregnancy. The coat of each lamb was evaluated for its fur characteristics within 48 hours after birth. The two groups of ewes differed in mean body weights, 0.6, 3.8, 7.8, 10.2 and 11.8 pounds progressively by months during pregnancy, and 7.5 pounds immediately after lambing. The high level ewes had a significantly shorter gestation period of 0.8 day. Average birth weights of lambs of 9.82 and 9.20 pounds respectively for the high and low groups differed significantly. Nutritional levels of pregnant ewes affected the pattern and general desirability of the lambskin fur, but after adjusting for differences in birth weight only pattern remained significantly different. Size, tightness and type of curl, and luster, texture and fur fiber length were not altered by the nutrition of the dams. Significant differences were noted in 7 of the 9 characters for the sires and in 6 of the 9 characters for the years. The problem of the Karakul breeder in lambskin fur production appears to be one of hereditary rather than nutritional considerations.

THE TREATMENT OF COBALT DEFICIENCY WITH VITAMIN B_{12} AND B_{12b}. S. E. Smith and B. A. Koch, *Cornell University*.

Our first attempt to treat cobalt deficient lambs with vitamin B_{12} failed. It is now evident that this failure was due to the use of inadequate amounts of B_{12}, for later trials using larger amounts have given prompt and complete cures. Twenty-five lambs were rendered cobalt deficient by feeding them a ration of low-cobalt hay, shelled corn and milk powder containing approximately 0.03 ppm. of cobalt. The typical signs of cobalt deficiency (lack of appetite, loss of weight and an anemia) were quickly alleviated when such lambs were injected with 150 mcg. or more of crystalline B_{12} over a two week period. In a further study, eighteen cobalt-deficient lambs were used to compare the effectiveness of cobalt salts when fed vs. injections of vitamin B_{12} or B_{12b}. Over a twelve week period the daily gains averaged 0.35 lb. and there was no significant difference among the three treatments. Thus it has been shown that vitamin B_{12} is an important intermediary in the metabolism of cobalt in sheep and furthermore that vitamin B_{12b} is as effective in this respect as vitamin B_{12} itself.

STUDIES CONCERNING THE NATURE OF AN UNIDENTIFIED GROWTH FACTOR FOUND IN FISH SOLUBLES. E. L. Stephenson, A. R. Camp, and P. R. Noland, *University of Arkansas*.

Weaned pigs were fed all-vegetable basal diets plus certain fractions obtained from fish solubles. One of the basal diets consisted of ground yellow corn, cotton-

seed meal, aureomycin, mineral and vitamin supplements. The other basal diet used was similar to this except that soybean oil meal replaced the cottonseed meal. These diets were supplemented with fish solubles and various fractions obtained from fish solubles. Present evidence indicates that fish solubles contain an unidentified "vitamin-like" factor which will promote growth of pigs when fed as a supplement to an all-vegetable ration containing all known required nutrients including vitamin B_{12} and aureomycin.

ANTIBIOTICS AND UNIDENTIFIED GROWTH FACTORS FOR GROWING-FATTENING PIGS FED "CORN-SOYBEAN OIL MEAL" RATIONS IN DRYLOT. S. W. Terrill, W. K. Warden, D. E. Becker and R. J. Meade, *University of Illinois.*

Six lots of 10 pigs each were self fed a 20% crude protein "corn-soybean oil meal" ration (fortified with minerals, vitamins A & D, riboflavin, calcium pantothenate, niacin and choline chloride) in drylot (concrete) from weaning to 100 lb. The treatment and average daily gain (lb.) for each lot were as follows: (1) basal, 0.86; (2) basal plus 7 mcg. vitamin B_{12} per lb. (B_{12} feed supplement), 1.01; (3) 2 plus 5 mg. crystalline aureomycin HCl per lb., 1.28; (4) 2 plus 5 mg. bacitracin (pharmaceutical grade bacitracin) per lb., 1.17; (5) 2 plus 5 mg. bacitracin (bacitracin feed supplement) per lb., 1.15 and (6) 1 plus 3% menhaden fish solubles plus 5 mg. bacitracin (bacitracin feed supplement) per lb., 1.17. Increases in rate of gain over Lot 2 of 27% (Lot 3) and 16% (Lot 4) were highly significant and significant respectively. Lots 2 and 4 were each subdivided into two equal groups for the period 100 to 200 lb. and subgroup treatments were the Lot 2 ration (15% crude protein) with and without bacitracin. Fastest gains occurred when bacitracin was included in the ration for the entire period from weaning to 200 lb. In another test (drylot, weaning to 100 lb.) a similar basal ration was used as in the first test with the further additions of thiamine, pyridoxine, folic acid, vitamin B_{12} and terramycin HCl. Treatments and daily gains (lb.) were as follows: (1) basal, 1.33; (2) 1 plus 10% dehydrated alfalfa meal, 1.20; (3) 1 plus 5% dried corn distillers' solubles, 1.36; (4) 1 plus 4% dried whey-product with whey fermentation solubles, 1.35 and (5) 1 plus 3% condensed menhaden fish solubles, 1.39.

THE VALUE OF AMMONIATED CONDENSED DISTILLERS MOLASSES SOLUBLES AS A FEED FOR BEEF CATTLE. A. D. Tillman and J. F. Kidwell, *Louisiana State University.*

Recently a new by-product has been developed by condensing the residue from yeast fermentation of cane molasses to commercial alcohol. This product, known as Ammoniated Condensed Distillers Molasses Solubles, has the following approximate chemical analysis: crude protein 4 to 5%; NFE 28 to 30%; water 39 to 40%; and ash 15 to 17%. As it will react with anhydrous ammonia, the nitrogen level can be increased to give a protein equivalent of approximately 13%. Two 56-day feeding trials were conducted. In the first trial 15 animals were divided into 3 lots of 5 each. In the replicate trial 12 heifers were divided into 3 lots. One-day weights were taken at the start and at 14-day intervals thereafter. The animals were hand-fed the concentrate ration once daily. Grass hay, water, and a mineral mixture were given ad libitum. Alfalfa hay was given at one feeding each week. The control ration consisted of corn 46%, molasses 31%, and cottonseed meal 23%. The second ration consisted of corn 40%, cottonseed meal 20%, molasses 30%, and Ammoniated Condensed Distillers Molasses Solubles 10%. The third ration consisted of corn 44%, cottonseed meal 16%, molasses 20%, and Ammoniated Condensed

Distillers Molasses Solubles 20%. The caloric intake from the concentrate feed was equalized for all three lots and restricted to produce approximately one-pound gain per animal per day. In the two trials no significant differences in gain were noted when the Ammoniated Condensed Distillers Molasses Solubles replaced 25% and 50% of the molasses in a normal ration for growing cattle. However, in both trials the lots receiving the ration with 20% Ammoniated Condensed Distillers Molasses Solubles made the lowest gains. The animals receiving Ammoniated Condensed Distillers Molasses Solubles made more efficient use of their feed during the latter part of each trial. This indicates that time is required to change the rumen microflora for utilization of rations containing Ammoniated Condensed Distillers Molasses Solubles.

THE VALUE OF SOLVENT-EXTRACTED RICE BRAN IN THE RATIONS OF GROWING-FATTENING SWINE. A. D. Tillman, J. F. Kidwell, and C. B. Singletary, *Louisiana State University.*

A feeding trial involving forty pigs divided into eight equal lots is reported. Solvent-extracted rice bran was fed at two levels in a fairly complete ration. The design was an incomplete factorial which included control rations. Both control rations contained corn as the main cereal grain and fish meal. They differed only in that one had 0.5 percent APF supplement containing vitamin B_{12} and aureomycin. In three rations the solvent-extracted rice bran was included at the level of 15 percent of the total ration. In the other three rations it was included at the level of 30 percent of the total ration. In each of these series of three rations, one ration contained fish meal and no APF supplement. There was also one ration containing fish meal plus the APF supplement and the third one contained no fish meal but the APF supplement. On the basis of these data the following conclusions seem justified: (1) When solvent-extracted rice bran replaced corn at the levels used in this trial, very satisfactory growth was obtained. (2) The solvent-extracted rice bran did not affect the firmness of fat. (3) The APF supplement significantly improved ($P \leqq .01$) the rations containing fish meal. (4) All-vegetable rations containing the APF supplement were equivalent to those containing fish meal without the APF.

A LIVER BIOPSY TECHNIQUE AND OBSERVATIONS OF ITS USE IN VITAMIN A STUDIES WITH BEEF CATTLE. W. J. Van Arsdell, C. K. Whitehair and R. W. MacVicar, *Oklahoma Agricultural Experiment Station.*

A liver biopsy technique for cattle has been perfected whereby a 1 to 2 gram sample of liver is obtainable. Over 100 liver samples have been collected, as often as at monthly intervals, with no apparent ill effect. Post mortem examination of the liver of animals biopsied 12 times showed only slight scarring of the liver tissue. This technique was used in studying vitamin A metabolism in beef cattle. Cows and steers were depleted of vitamin A stores by feeding a ration composed of cottonseed cake, straw and a mineral mixture. After a suitable depletion period, varying amounts of a carotene concentrate were supplemented and the concurrent levels of vitamin A and carotene in blood and liver were determined. Carotene concentrate to supply 2 and 8 times the minimum daily requirement (30 micrograms per kg. body weight) failed to maintain carotene and vitamin A stores in the liver. The level of carotene and vitamin A in the plasma remained essentially constant. Supplementation with a carotene concentrate to provide 16 times the minimum requirement of carotene, increased the amounts of vitamin A and carotene in the liver and blood. From these data, it appeared that there was correlation between the blood plasma level

and liver stores of vitamin A and carotene only at increasingly high levels of carotene intake.

REPRODUCTION OF RANGE EWES INCREASED BY ADEQUATE FEEDING. J. L. Van Horn, Wm. H. Burkitt, Fred S. Willson, Alva E. Flower, James Drummond and G. F. Payne, *Montana Agricultural Experiment Station.*

A band of 1082 ewes was separated into three groups immediately after breeding. The groups were equalized for age and breeding. One group (group A) was grazed on the range during the winter without any supplemental grain or pellets until lambing time. A second group (group B) was grazed with group A, but were separated each morning into four groups and fed ⅓ pound per head of pellets ranging from 10 to 40 percent protein. The third group (group C) was taken out of the band immediately after breeding and wintered on a full feed of hay plus ⅓ pound of a concentrate pellet and ⅓ pound of dehydrated alfalfa pellets each containing approximately 20 percent protein. There was a difference in the number of lambs born in the different groups. The group not receiving supplement to the range forage had an 80 percent drop, group B which received pellets in addition to the range had a 105 percent drop, and those on the highest level of feed had a 117 percent drop. This percentage was figured on the number of the ewes at lambing time. These three groups were also compared to another band of over 1000 ewes which was on a high plane of nutrition before and during breeding as well as through the winter. The percent of lambs born in this latter group was 126 percent. This was higher than any of the three groups in the first band.

ANTIBIOTICS STUDIES WITH DAIRY CALVES. H. H. Voelker and J. L. Cason, *University of Arkansas.*

During the past year forty Jersey and Holstein calves were involved in 3 experiments. Terramycin and aureomycin feeding supplements were used. The terramycin supplement contained 5.0 grams crystalline terramycin hydrochloride per pound. The Aurofac contained 1.8 grams aureomycin and 1.8 mg. Vit. B_{12}/lb. In experiment I, calves fed 30 mg. terramycin/100 lb. body wt. daily, gained 63 lb. average while controls gained 52 lb. The higher level of feeding terramycin produced statistically significant responses. In experiment II, 7 calves at 100 mg. terramycin level of feeding gained 28% more than 7 control calves. Calves receiving terramycin did not have greater feed efficiency, but consumed more feed (free choice). In experiment III, 10 calves were fed Aurofac (2.5% of grain ration) while on pasture for 8 wks. starting at an average age of 4.8 months. Ten calves served as controls. During the first 6 wks. the Aurofac calves gained 17% more than the controls. These differences were statistically significant. A series of measurements of 8 different body parts of each calf showed greater structural body growth of the Aurofac fed calves. Calves on all experiments showed firmer feces when fed antibiotics. Attempts to induce scours by fecal inoculation daily, orally by capsule were unsuccessful. No harmful effects were observed in feeding 200 mg. daily of pure aureomycin plus 2.5% Aurofac in the grain ration. Bacteriological studies of colon material showed no consistent differences in bacteria population due to antibiotic feeding.

A STUDY OF LYXOFLAVIN IN PIG NUTRITION. R. C. Wahlstrom and B. Connor Johnson, *University of Illinois.*

Two experiments have demonstrated that additions of lyxoflavin to the basal ration resulted in significantly greater gains with baby pigs. The basal

ration consisted of sucrose, 68%; casein, 25%; and minerals, 6%. These materials were dissolved in a sodium bicarbonate solution and made into a "synthetic milk" containing 19% solids. One percent cottonseed oil and all of the known vitamins were added in adequate amounts at the time of feeding. In addition, 0.1% of protamone was added in experiment 1 and 0.01% in experiment 2 to enhance the development of a deficiency state. Six 2-day-old Hampshire pigs (experiment 1) and six 2-day-old Chester White pigs (experiment 2) were used in this study. These pigs were divided into two groups, Group I which received the basal ration and Group II which received the basal ration plus 4 μg. of synthetic L-lyxoflavin per gram of diet. The addition of lyxoflavin resulted in significantly greater average total gains at five weeks ($P>0.02$) and a highly significant difference at seven weeks ($P=0.004$). There was no significant difference in efficiency of feed utilization.

EFFECT OF REDUCING AND DISCONTINUING AUREOMYCIN SUPPLEMENTATION DURING THE GROWING-FATTENING PERIOD OF THE PIG. Harold D. Wallace, William A. Ney, Luther T. Albert, and Tony J. Cunha, *University of Florida.*

All animals in both trials were fed a basal ration which consisted of yellow corn 56.5, peanut meal 41.5, bone meal 0.5, limestone 1.0, and a salt-trace mineral mixture which included Fe, Co, Cu, Mn, and I, 0.53 parts. This ration also contained the seven crystalline B-vitamins, thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, choline, and folic acid, at levels calculated to insure sufficiency. One mg. of vitamin B_{12} was added per 100 pounds of ration. In the first trial the pigs were fed this ration supplemented with 1 gram of crystalline aureomycin per 100 pounds from weaning until they averaged 100 pounds in weight. They were then divided into 3 lots (5 pigs per lot) and fed to 200 pounds. Lot 1 was continued on the same ration, lot 2 was reduced to .5 of a gram of aureomycin per 100 pounds of feed, and aureomycin was completely removed from lot 3. The average daily gains and feed requirements per 100 pounds gain were 1.50, 268; 1.65, 340; and .86, 381; for the three lots, respectively. In a second trial a group of animals were similarly treated except that they weighed approximately 120 pounds when the aureomycin supplementation was altered. There were 6 animals per lot and the gains after 5 weeks with lot treatment the same as in the first trial were 1.55, 1.35, and .98.

VARIOUS ANTIBIOTICS IN CORN-PEANUT MEAL RATIONS FOR WEANLING PIGS. Harold D. Wallace, William A. Ney and Tony J. Cunha, *University of Florida.*

The basal ration consisted of corn 56.5, peanut meal 41.5, bone meal 0.5, limestone 1.0 and a salt-trace mineral mixture which included Fe, Cu, Co. Mn and I, 0.53 parts. This ration also contained the seven crystalline B-vitamins, thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, choline, and folic acid at levels calculated to insure sufficiency. One mg. of vitamin B_{12} was added per 100 pounds of basal ration. Seven lots of six pigs each, averaging approximately 32 pounds, were self-fed on concrete floors. The following materials were added per 100 pounds of feed: lot 1 (control), lot 2—1.0 gram aureomycin, lot 3—2.0 grams aureomycin, lot 4—2.0 grams terramycin, lot 5—2.0 grams chloromycetin, lot 6—2.0 grams bacitracin, and lot 7—1.7 grams of 3-nitro-4-hydroxyphenyl arsenic acid. Average daily gains over a ten-week period for the seven lots were, respectively: .62, 1.07, 1.27, 1.18, .66, .48, and .77. Respective figures for feed

required per 100 pounds of gain were as follows: 307, 333, 273, 294, 392, 470, and 251.

A STUDY OF CERTAIN PLANT AND ANIMAL SOURCES OF CRUDE PROTEIN FOR WEANLING PIGS FED IN DRYLOT. W. K. Warden, S. W. Terrill, D. E. Becker and C. R. Adams, *University of Illinois.*

Four sources of protein were studied using semi-purified diets containing 5 mg./lb. procaine penicillin and equalized for fat, fiber and vitamins: Lot I dried skim milk, Lot II new-process solvent soybean oil meal, Lot III blended solvent soybean oil meal, Lot IV blended meat and bone scraps (50% C.P.). Each test ingredient was incorporated in the ration to supply 11% crude protein. Chester White weanling barrows were hand fed for 37 days. Gain per lb. of protein consumed (lb.) and daily gain (lb.) respectively, were: Lot I, 4.54, 1.43; II, 3.61, 1.01; III, 3.23, 0.88; IV, 1.67, 0.40. The daily gains between lots differed significantly in all cases, except between lots II and III. Six lots of pigs were group fed various sources of supplemental protein in rations consisting of yellow corn, minerals, vitamin A and D supplement, B-vitamins and procaine penicillin (2 mg./lb.) with B_{12}, from weaning to 100 pounds. Level of crude protein fed, supplemental protein, and daily gain (lb.) respectively, were: I, 18%. blended soybean oil meal, 1.23; II, 16%, blended soybean oil meal, 1.27; III, 18%, new-process soybean oil meal, 1.14; IV, 16%, new-process soybean oil meal, 1.14; V, 18%, blended meat and bone scraps, 0.96; VI, 18%, blended meat and bone scraps plus .1% DL-tryptophan, 1.24. Daily gains of Lots I, III, IV and VI were significant over Lot V. There was no significant difference in gains between the two levels of crude protein fed.

MILK PRODUCTION OF MATURE RANGE EWES AS AFFECTED BY THE LEVEL OF PROTEIN IN THEIR RATION. Frank Whiting and Sydney B. Slen, *Experimental Station, Lethbridge, Alberta, Canada.*

Milk production studies were conducted with 3 and 4-year-old range ewes from the 1st to 7th week of lactation by weighing the lambs before and after each nursing (4-hour intervals) during two 24-hour periods each week. The rations, individually fed, provided 0.11 pound of digestible crude protein per head daily throughout pregnancy and lactation to Lot 1, 0.11 pound during the first 3½ months of pregnancy and 0.25 pound during the last 6 weeks of pregnancy and during lactation to Lot 2, and 0.25 pound throughout pregnancy and lactation to Lot 3. Average body weights of the ewes during lactation was 128 pounds. Twelve ewes in Lot 1 and 14 ewes in Lots 2 and 3 completed the lactation study. The ewes in Lot 1 produced significantly ($P \geqq 0.01$) less milk than the ewes in Lots 2 and 3 (29.6 ounces daily vs. 42.5 and 42.2 ounces daily, respectively). The average percent protein (fat-free basis) was significantly increased ($P \geqq 0.01$) with each increase in protein intake (4.49% for Lot 1, 4.76% for Lot 2 and 4.94% for Lot 3). The average gain of the lambs (all raised as singles) from birth to 7 weeks was significantly ($P \geqq 0.01$) correlated ($r=0.76$) with milk production of the ewe. For each ounce increase in average daily milk production during the first 7 weeks of lactation the lambs gained 0.48 pound more to 7 weeks of age.

INFLUENCE OF INTERRUPTED GROWTH OF STEERS ON CARCASS QUALITY AND FEED ECONOMY. C. F. Winchester, *U. S. Dept. of Agriculture.*

Six pairs of identical twin beef steers and two pairs of fraternal twins were used to determine the effects of interrupted and decelerated growth. One member

of each twin pair was fed according to its capacity, while the other was given, for a period of 6 months or more, a ration limited with respect to its caloric value. Three experimental animals were given rations just above maintenance, two were fed about 62 percent and three about 75 percent of Morrison's more liberal allowance for beef calves. Of the animals given the smallest allowance, one lost 4 pounds and the other two gained 16 and 34 pounds respectively during a period of 6 months; those fed the 62 percent ration gained about a half a pound daily, and the animals given the 75 percent ration gained around a pound per day. Daily gains of controls were from 1½ to 2¼ pounds. After the end of the period of limited-feeding, experimental steers fed according to their respective capacities, grew rapidly and gained weight economically. Both controls and experimental animals were slaughtered when the individuals reached 1000 pounds of body weight. Energy required by the experimental animals to reach the final weight compared favorably with that consumed by controls. Data on carcass quality and composition were recorded.

Pasture, Forage and Range Section

L. E. Harris, *Chairman*

THE SUPPLEMENTATION OF GROUND CORN COBS, SOYBEAN STRAW, OAT STRAW, CORN SILAGE AND "GRASS SILAGE" FOR WINTERING STEER CALVES AND YEARLINGS. W. M. Beeson and T. W. Perry, *Purdue University Agricultural Experiment Station.*

Five trials were conducted to study the growth response of Hereford and Shorthorn steer calves and yearlings when ground corn cobs, soybean straw, oat straw, corn silage or "grass silage" was fed as the sole source of roughage during the wintering period. Each steer received, in addition to the roughage being tested, minerals free choice (bonemeal, limestone, salt, iodine and cobalt) and 3.5 lb. of "Purdue Cattle Supplement A" per day (from "Purdue Cattle Supplement A" each steer received a daily feed of 2.25 lb. soybean meal, 1 lb. molasses feed, minerals, and a Vitamin A and D concentrate—2250 A—400 D cod-liver oil). When the individual roughages were fed with "Purdue Cattle Supplement A", the following average daily gains were obtained: ground corn cobs, 1.28 to 1.56 lb.; soybean straw, 0.78 lb.; oat straw, 0.78 lb.; corn silage 2.06 to 2.21 lb.; grass silage, 2.01 lb. Some lots of steers, receiving ground corn cobs as the sole source of roughage, received the following modifications of "Purdue Cattle Supplement A" and gave the following daily growth responses: control animals receiving "Purdue Cattle Supplement A", 1.28 lb.; urea furnishing from ⅓ to ⅔ protein equivalent. 1.25 to 1.14 lb.; ¼ protein from fish meal, 1.38 lb.; 0.01 percent live cell yeast, 1.36 lb.; 0.01 percent Vitamin B_{12} supplement, (Merck's), 1.35 lb.; 2 lb. distiller's dried solubles per day, 1.19 lb.; 0.01 percent Brewer's yeast, 1.28 lb.; 2 lb. alfalfa meal per day, 1.42 lb. Comparable animals receiving only mixed clover-timothy hay and the same mineral mixture gained from .72 to .88 lb. per day.

THE EFFECT OF WATER ON LIVESTOCK IN WESTERN STATES AREA. Neil P. Brennan, *Blue J Feed Company.*

Nearly ten years ago, at Brittain, South Dakota, wells that had been low suddenly had a more abundant supply—evidently from percolating underground waters. This water contained fluorine in sufficient quantity to cause death loss.

The same year near Wessington Springs, South Dakota, under similar conditions there was an increase in sodium chloride. Although no great loss was experienced, there were a few incidents of urinary calculi through this section of South Dakota, western Nebraska and Wyoming. In fact, only in the feed lots where considerable lamb feeding took place did feeders and veterinarians have this problem. Recently reports have been received from ranchers and farmers in almost every section where water supply is from improvised dams. Under varied feed programs urinary calculi still seems to increase. One test made of drinking water showed 52 parts per million of solids; the next one 212; then as follows: 224; 417; 524; 1500; 3500; 4600; then 15500 ppm. The materials listed were principally sodium sulfate, magnesium sulfate, calcium sulfate; and the report on hardness varied from 50 gr. to 1500 gr.

DETERMINING THE DIGESTIBILITY AND METABOLIZABLE ENERGY OF WINTER RANGE PLANTS BY SHEEP. C. Wayne Cook, and Lorin E. Harris, *Utah State Agricultural College.*

The conventional method of estimating the feeding value of domestic feed crops is inadequate for range forage. This is particularly true for common energy values (total digestible nutrients). Important constituents in appraising the value of range forage in the Intermountain Area are: digestible protein, available energy, phosphorus and carotene (vitamin A). Accurate appraisals of these constituents are needed for determining deficiencies of range forage, compounding supplements for range animals, and in comparing the value of the various forages. In evaluating rations or diets of animals on the winter range metabolizable energy values are suitable but are not in common use. Metabolizable energy values are more accurate than T.D.N. or digestible energy because they take into account the loss of energy through the urine. This is of great importance in appraising the energy supplying qualities of range forage plants high in essential oils. A method for determining digestibility and metabolizable energy of native forage under range conditions is presented. Wether sheep equipped with specially constructed fecal bags and urinals were allowed to graze temporary enclosures on native forage types composed of single species. The lignin ratio technique was used to determine the digestibility and forage intake. It was found that species judged to be excellent forage because they are highly preferred by grazing animals, are not always the most nutritious, and in addition it was observed that metabolizable energy was perhaps the most suitable index to the energy supplying qualities of range forage.

CORN SILAGE VS. LEGUME-GRASS SILAGE FOR WINTERING BREEDING COWS. C. J. Cunningham and E. A. Livesay, *West Virginia University Agricultural Experiment Station.*

Two lots of 15 bred cows each were wintered for five years—one lot receiving two thirds of the dry matter of the rations from corn silage and the other two thirds of the dry matter of the rations from legume-grass silage. These cows were started as "yearling-plus" bred heifers. The rations were entirely roughage (⅔ dry matter from silages and ⅓ dry matter from hay) except for the first winter. The "yearling-plus" bred heifers had their rations balanced by adding cracked corn to the legume-grass silage ration and by adding soybean meal to the corn silage ration. The results at the end of five years indicate that the two silages were of approximate equal value (on a dry matter basis). The development of the cows were the same for both lots. The calves from the two lots were approximately the same weight at birth, but the calves of the legume-grass silage lot made slightly more summer gains and were an average of ten pounds heavier at weaning time.

INFLUENCE OF WINTERING AND GRAIN FEEDING ON RETURNS FROM TWO-YEAR-OLD AND YEARLING GRASS STEERS. H. R. Duncan, C. S. Hobbs, J. Hugh Felts, J. W. Cole, and R. P. Moorman, *University of Tennessee.*

Pasture-wintering cattle produced slightly more total gain at a somewhat lower cost than cattle wintered in the barn. These pasture-wintered cattle were appraised slightly higher and returned $25.00 more profit per head for both ages than those wintered in barn on silage and hay. In an average of three trials, feeding grain the last 56 days on grass produced only 37 lbs. more gain on the two-year-old cattle and 27 lbs. more on the yearling cattle than those receiving grass only. The grain-grass two-year-old steers were less than ⅓ of a slaughter and carcass grade higher than the grass steers but dressed 1.5 percent more. The grass-alone steers returned $1.97 more profit. Neither lot of yearling steers carried a satisfactory finish on September 20 when the two-year olds were sold, but graded as high on slaughter and carcass grade and dressed as high after a 56 day dry-lot finish to November 23 as the older cattle did on September 20. The yearling steers which had no grain the last 56 days on grass returned slightly more profit ($2.51) than those which had grain that period. The yearlings as handled produced 106 lbs. more gain than the two-year olds, at a slightly lower cost, were appraised at same price, dressed practically the same, had the same carcass grade, but returned $16.52 more over feed and initial cost than the two-year-olds. The carcasses were lighter, more easily merchandized and more desirable for the area beef trade than the two-year-olds.

DEGREE OF SELECTIVE GRAZING BY STEERS AS EVIDENCED BY FECAL COMPOSITION. W. A. Hardison, J. T. Reid, and C. M. Martin, *Cornell University.*

Although it is commonly believed that animals graze selectively, there are very limited supporting data available. Also, there are no available data which demonstrate the degree of selective grazing under various conditions. For these reasons a study was made of the composition of the feces of steers which were hand fed clipped, whole forage and of that of steers allowed to graze successively small areas of the same pastures throughout the grazing season. The digestibility of the clipped, whole forage was compared to that of the grazed forage using the fecal chromogen indicator method reported previously. The composition of the feces of hand-fed and of grazing steers was found to be greatly different. For example, the feces of grazing steers contained a higher level of protein and fat and a lower level of crude fiber than those of steers hand fed the whole forage. The ranges of dry matter digestibility of the clipped, whole forage and of the grazed forage were 74.0 to 51.6% and 76.2 to 52.9%, respectively. In a study of 15 pasture forage mixtures the digestibility of the clipped, whole plant was found to be 91.6% of that of the forage selected by grazing animals. Since an attempt was made to graze small areas to a height approximately the same as that of the stubble of the clipped areas (although this was not accomplished), it is believed that grazing was restricted in these trials. Consequently, greater differences may be found under conditions of freer grazing. Other trials in which free-grazing conditions are being imposed are in progress.

EFFECT OF FEEDING VARIOUS LEVELS OF PHOSPHORUS, PROTEIN, AND ENERGY TO RANGE EWES BY THE USE OF A FACTORIAL DESIGN. Lorin E. Harris, and C. Wayne Cook, *Utah State Agricultural College.*

During the winters of 1948–49 and 1949–50 27 ewes of each of six age groups from lambs to ewes over six years old, or a total of 162 ewes, were assigned at

random to 27 treatments. These treatments consisted of three levels of three supplemental feeds in all combinations: barley for energy, monosodium phosphate for phosphorus, and soybean oil meal for protein. The three levels of barley or soybean oil meal fed were 0 grams, 128 grams, and 256 grams; and the three levels of monosodium phosphate fed were 0 grams, 13 grams, and 17 grams. The ewes were fed every other morning in individual pens during the period they were grazing on the winter range. In addition to the ewes in the factorial design, there were 36 control ewes that received only range forage. The supplements prevented excessive weight losses and increased the wool production and percentage lamb crop over that of the control ewes. The amount and ratio of phosphorus to protein is important in producing maximum amounts of wool and lambs. Evidence is presented to show that the factorial design yields a maximum amount of data for each animal used in the experiment.

FINISHING WESTERN WETHERS ON WINTER PASTURE. Henry H. Leveck and David R. Pingrey, *Mississippi Agricultural Experiment Station.*

The results of three tests completed at the Mississippi Experiment Station demonstrate the possibility of finishing Western ewe and wether lambs on winter pasture in the Southeast. Three groups of lambs, averaging 26 lambs per group, were grazed on crops of Italian rye grass, Balbo rye and oats from mid-December to mid-March or an average period of 86 days. The lambs used averaged 65.6 pounds initially and were of Hampshire-Rambouillet breeding from Montana and of Correidale-Rambouillet and Suffolk-Rambouillet breeding from Texas and New Mexico. The results of these studies showed that the lambs pastured on Italian rye grass led in daily gains with a gain of .4 pounds, followed by the lambs on oats and Balbo rye with a gain of .38 pounds daily. Gains per acre were greatest for the lambs on Italian rye grass with an average gain of 176.5 pounds followed by the lambs on oat pasture with a gain of 155.1 pounds with the lambs on Balbo rye showing the lowest gain per acre, 140.4 pounds.

The lambs would have graded from High Medium to Middle Good as fat lambs at the end of the grazing period. One group was sold at that time and was well received by the packers, a second group of ewes was retained as breeders with a third group carried on spring clover pasture and sold by mid-May. All groups showed a satisfactory profit favoring the group clipped in March and sold off clover pasture in May.

EFFECTS OF PHOSPHATE FERTILIZATION AND OF DIETARY MINERAL SUPPLEMENTS ON THE NUTRITIVE VALUE OF SOYBEAN FORAGE. G. Matrone, V. B. Weldon, W. W. G. Smart, Jr., F. H. Smith, H. M. Baxley, and G. H. Wise, *U. S. Plant, Soil and Nutrition Laboratory, and North Carolina Agriculture Experiment Station*

The nutritive value of differentially-phosphate fertilized soybean forages, 1948 and 1950 crops, was assayed by means of rabbits in two series of trials. Each test diet consisted, by weight, of 100 pts. of the respective soybean hays studied, 25 pts. of glucose ("Cerelose"), and 5 pts. of refined cottonseed oil ("Wesson"). In the first series, in which both *ad lib.* and paired-feeding systems were employed, comparisons of gains in weight from hays grown on phosphated and non-phosphated soils revealed no significant difference. In the second series, in which the test diets (fed *ad lib.*) were modified by replacing 8 gms. of "cerelose" with an equal weight of egg albumin, the diets containing hays from phosphate-treated soils effected significantly greater gains than did those containing the non-phosphate fertilized hays. The blood from rabbits fed the former diet also contained higher levels of hemoglobin, serum inorganic phosphorus and serum magnesium than did the blood

from animals on the latter. The rabbits on this low phosphorus diet also developed brittle fragile bones. In further studies of the hays from phosphated and non-phosphated soils other rabbits were fed these forages in diets in which the calcium and phosphorus content of the comparative feeds were equalized by additions of dicalcium phosphate and calcium carbonate. This supplementation eliminated differences observed in the non-supplemented diets; thus, indicating that the phosphorus concentration was the primary factor involved in the nutritional differences of the hays from phosphate and from non-phosphate fertilized soils.

OBSERVATIONS ON THE USE OF THE CHROMOGEN TECHNIQUE IN DETERMINING FORAGE CONSUMPTION OF MILKING COWS. C. H. Noller, D. L. Hill and N. S. Lundquist, *Purdue University*.

A study of the forage consumption of three mature Holstein cows on pasture was made to determine the extent to which high levels of milk production could be maintained. The chromogen (s) technique of Reid et al. (1950) was used to determine the apparent digestibility and chromium oxide to measure intake. These cows received no supplementary feed except bonemeal and salt. The cows were rotated at intervals, depending on the condition of the pasture, so that maximum feed was available at all times. Preliminary data for 84 days indicated an average apparent digestibility of 75.34, 72.29 and 70.33 percent. These cows produced a daily average of 54.9, 40.0, and 37.9 lbs. of FCM for the period. Their respective body weights showed no change, an increase of 47 lbs., and an increase of 52 lbs. Data gathered indicate that under the conditions of the experiment, cows can consume more than enough grass to meet their requirements. These cows consumed a daily average of 225 pounds of grass. On very luxuriant pasture the cows consumed more.

Physiology Section

H. H. Cole, *Chairman*

ENDOCRINE CAUSES OF GENETICALLY DIFFERENT GROWTH RATES IN HAMPSHIRE SWINE. D. M. Baird, A. V. Nalbandov and H. W. Norton, *University of Illinois*.

After nine generations of selection for slow and rapid rates of gain two genetically different strains of Hampshire swine were developed differing greatly in their ability to gain and in their economy of feed utilization for growth. While studying some of the underlying physiological causes of these differences the anterior pituitaries from 86 animals from both strains were paired by sex and age at 56, 75, 115 and 154 days and at market weight (225 lbs.) and were assayed individually for their growth hormone content. Immature hypophysectomized female rats weighing 50 grams were used as assay animals. The index of the growth hormone potency was the change in urinary nitrogen retention, body weight, and the widening of the uncalcified cartilage at the proximal end of the tibia following the daily injection of a 50 gamma suspension of desiccated pituitary tissue for a four day period. The results of this test show the width of the epiphyseal cartilage to be the most critical and sensitive test for the assay of growth hormone followed by the increase in body weight. Nitrogen retention was least sensitive and gave the most variable results. At all ages the anterior pituitary of the rapidly growing strain contained significantly more growth hormone on a weight basis. Sex did not influence the growth hormone potency of the pituitaries. It was generally found that

the heavier animals had heavier pituitaries but on a body weight basis the smaller animals had proportionally heavier glands. One of the physiologic causes responsible for the genetic differences observed lies in the rate of growth hormone production by the two lines.

STUDIES RELATING TO MILK FEVER IN DAIRY COWS. J. M. Boda and H. H. Cole, *University of California.*

Preliminary work has been undertaken in an attempt to decrease the incidence of milk fever in dairy cows by feeding a low calcium, high phosphorus ration for several weeks prior to parturition. In one experiment four cows were divided into two groups. Two animals received a low calcium, high phosphorus ration, the other two received the same ration excepting that bone black was substituted for monosodium-phosphate. Blood samples were collected periodically before, at, and after parturition and analyzed for total serum calcium and phosphorus. In one animal receiving the low calcium diet, the serum calcium level increased after parturition, reached a peak of 13.5 mg.-% on the fourth day and then declined to normal levels. Serum calcium levels in the other three animals did not show this post-partum rise. A field experiment involving 36 Jersey cows, many of which have previous histories of milk fever, is now in progress. One group is receiving a similar low calcium, high phosphorus diet. A second control group is maintained on permanent pasture. At the present date twelve of these animals, six experimental and six controls, have calved. Two of the controls have exhibited a drop in serum calcium levels to 5.59 mg.-% and 4.35 mg.-% respectively, at parturition and have developed milk fever. In the experimental group, the serum calcium levels have remained above 8.0 mg.-% and none has developed milk fever.

THE EFFECT OF THE MALE SEX HORMONE ON RATE OF GAIN AND FEED EFFICIENCY OF BEEF CATTLE. Ralph Bogart, A. C. Warnick, J. J. Dahmen, and Martin J. Burris, *Oregon Agricultural Experiment Station.*

Bulls gained more rapidly and efficiently than steers, and the latter were superior to heifers in both rate and efficiency of gains. To study the physiology of these differences, three steers and three heifers each were injected weekly with 1 mg. per kg. of body weight of testosterone in the form of aqueous suspension of micropellets (Oreton-F) and three steers and three heifers each were given the same amount of methyl androstenediol in aqueous suspension (Methostan). Both hormones were given intramuscularly. A control group of six steers and six heifers sired by the same bulls as those receiving hormones was used. The test period was from a weight of 500 lbs. to a weight of 800 lbs. Gain and feed records were kept on each individual for this period. Testosterone-injected calves gained 0.4 lbs. per day more per animal and required 100 lbs. T.D.N. less for each 100 lbs. gain made than the controls. Heifers and steers receiving testosterone injections were practically equal in rate of gain and feed efficiency whereas control heifers gained at a slower rate and required more feed for each unit of gain than control steers. The non-masculizing hormone, methyl androstenediol, did not influence rate of gain or feed efficiency in either steers or heifers. It appears that increased rate of gain and feed efficiency are associated with the masculizing principle of the male hormone.

SIMPLE AND MULTIPLE CORRELATIONS BETWEEN SEMEN TESTS AND BULL FERTILITY. P. J. Buckner, E. L. Willett and Ned Bayley, *American Foundation for the Study of Genetics and University of Wisconsin.*

Three series of studies, involving a total of 197 samples from 39 bulls, have been made of the correlation between various proposed tests of semen quality and

bull fertility. The analyses have included within-bull and between-bull correlations. With three tests a between-bull, multiple correlation coefficient of 0.90 has been obtained in the first series. In the two later trials corresponding coefficients have been lower. These three tests included methylene blue, motility of fresh spermatozoa, and drop in progressive motility of spermatozoa in a 3% aniline blue solution during 120 minutes. The following conclusions have been drawn: (1) Coefficients in the neighborhood of 0.90 or higher are necessary to enable accurate prediction of fertility. On the basis of work by others as well as by ourselves, it appears that no single test yet devised is correlated with fertility to this degree. (2) In these studies the only combinations of practical tests that have approached this requirement are those based upon between-bull, multiple correlations. Such correlations indicate that tests, when based upon several samples from each bull, would enable selection of bulls for fertility but would not enable prediction of fertility of individual samples. (3) The contribution that an individual semen test makes, when used in combination with other tests, toward increasing the multiple correlation should be the main consideration when determining its value.

EFFECTS OF STILBESTROL ON BEEF HEIFERS AND STEERS. M. T. Clegg, H. H. Cole and H. R. Guilbert, *University of California.*

Earlier experiments by Andrews and coworkers have demonstrated significant increases in body weight after implantation of stilbestrol pellets. We have undertaken several field trials to determine the effect of this hormone under different feed conditions. Animals in feed lot received implants of 5 pellets of 12 mgs. each. The treated groups in most instances made greater increases in body weight and gain per day than the controls. Preliminary data indicate no significant gains in grass fattened animals. Carcass grades at time of slaughter were, in all cases, poorer in the treated groups. In both heifers and steers, the hormone caused significant mammary development. Considerable milk was present in the mammary glands of the heifers at the time of slaughter. Vaginal prolapses occurred in two trials. In one group of eighty Hereford heifers treated with 60 mgs. of stilbestrol, four developed vaginal prolapse. In another group of ten Hereford heifers one animal became prolapsed. At the time of slaughter pituitaries, adrenals, thyroids, and ovaries were collected and saved for histological study. Weights of the pituitaries and adrenals were increased above the controls. No significant differences in weight were found with regard to the thyroids and ovaries. A histological study of these glands is being undertaken to detect any aberrant changes in the character of the tissues.

THE MILK SECRETION RESPONSE OF THE BOVINE TO INJECTED GROWTH HORMONE. John D. Donker and W. E. Petersen, *University of Minnesota.*

A growth hormone (preparation kindly furnished by Dr. Irby Bunding of Armour and Company) has been injected into seven cows in nine trials. The response was measured as a % change in milk weight using a preinjection period as a base. Two, four, and eight days' post-injection milk weights were compared to a like number of days' pre-injection milk weights (base). Except in a single trial there was a positive response shown in all of the comparison periods. This animal with the negative results was a particularly unresponsive milk animal as shown by the fact that she produced *5.3*# B.F. in *58* days (total lactation). Her data are omitted. Increases of $12.4 \pm 9.6\%$, $19.5 \pm 15.5\%$ and $15.9 \pm 16.9\%$ for the two, four and eight day comparison periods were seen. The average increase from two single intramuscular injections was 11.6% compared to a 9.1% average increase for two single subcutaneous injections for the four day comparisons. Over a like

period, two multiple intramuscular injections brought about a 36.4% average increase compared to an average increase of 21.2% for two multiple subcutaneous injections. Four single injections resulted in an average increase of 10.3% while four multiple injections resulted in an average increase of 28.8% over the four day periods. In the eight day periods this increase was 4.4% and 27.5% with the higher value corresponding to the multiple injection trials.

FERTILITY RATE AND EMBRYONIC DEATH LOSS IN EWES EARLY IN THE BREEDING SEASON. R. H. Dutt, *University of Kentucky*.

One hundred and eighty crossbred yearling ewes were paired as they came in heat and each was inseminated with 0.2 c.c. of a split portion of undiluted semen. The study was conducted over a period of three years and breeding was started the last week in August and continued through September. One ewe from each pair was slaughtered three days after breeding to determine the ovulation rate, condition of the ova, and fertility rate. The remaining ewes made up the control group and were checked for return to heat and allowed to go to lambing time. All ewes (90) in the slaughter group had ovulated; the ovulation rate was 1.47 per ewe, and 96.2% of the ova were recovered of which 55.1% had been fertilized. No gross abnormalities of the reproductive tract were found in any of the ewes. At three days 20.5% of the ova were classified as abnormal. The abnormal ova may be subdivided into two classes: (1) cleaved—containing ruptured or disintegrating cells, 58.8%; and (2) uncleaved—vitelline membrane ruptured, zona pellucida cracked or only a portion of broken zona pellucida found, 41.2%. Using the ovulation and fertility rate from the slaughter group as estimates for the control group, lambs born represent 40.2% of the ova and the estimated embryonic death rate was 24.3%. The reproductive performance of the ewes may be classified as follows: (1) no fertile ova, 38.9%; (2) death of embryo, 20.0%; and (3) lambed, 41.1%.

A PRELIMINARY REPORT ON THE EFFECTS OF FEEDING LARGE QUANTITIES OF GRASS SILAGE TO DAIRY BULLS. R. J. Flipse, D. L. Thacker and J. O. Almquist, *The Pennsylvania State College*.

Twelve Holstein, Guernsey and Jersey bulls two to nine years of age were paired as to breed, age, weight and semen quality, and pair members randomly allotted to two experimental groups. Bulls in group I received daily four pounds of grass silage per hundredweight plus sufficient hay to bring the total TDN intake up to the recommended allowances of the National Research Council. Each group II bull received the same amount of hay as his pair mate in group I but received a concentrate mixture in place of and equal in TDN to the silage. During the pre-experimental period all bulls received hay and grain. Two semen samples were collected from each bull at weekly intervals. During the 28-week experimental period, the average increases for groups I and II, respectively, were weight, 262±52 and 189±53 pounds; heart girth, 1.79±1.08 and 1.66±1.11 inches; paunch girth, 4.63±0.97 and 1.83±0.99 inches and height at withers, 4.25±2.08 and 4.75±2.07 cm. Average semen values for combined ejaculates for groups I and II, respectively, were volume, 4.59±0.58 and 4.58±0.62 ml.; concentration of sperm per ml., 1342±174 and 1279±134 x 10^6; initial motility, 56.5±2.7 and 57.4±2.5%; unstained (living) sperm with eosin-aniline blue, 65.3±3.9 and 65.7±2.6%; acid phosphatase, 5.59±0.71 and 6.99±0.35 units per ml. and alkaline phosphatase, 5.04±0.64 and 4.03±0.52 units per ml. From these data and subjective observations of the bulls it appears that large amounts of grass silage can be fed safely to dairy bulls. However, the experiment is being continued to cover a full year of silage feeding.

THE COLORIMETRIC DETERMINATION OF THE EXCRETION PRODUCTS OF PROGESTERONE AND THEIR CORRELATION WITH CERTAIN PHENOMENA OF PREGNANCY IN THE SOW. Betty Ruth Glasgow, D. T. Mayer and G. E. Dickerson, *University of Missouri.*

The concentration of the products of progesterone metabolism in sow urine was determined and correlated with observed changes in the reproductive tracts during the early phases of gestation. The chemical procedure employed for the extraction of the progesterone excretion products from the urine is essentially that of Astwood and Jones. During the extraction procedure, a purification method suggested by unpublished work of Miller and Mayer was employed. The quantity of the excretion products in the urine was then determined colorimetrically by a method described by Goldzieher. Preliminary results indicate that progesterone metabolic products in the urine vary during certain phases of the gestation period. Significant correlations between concentration of progesterone excretion products and number of embryos implanted, and between the concentration and the percent of ova shed resulting in viable embryos indicates that some factor other than the number of placentae and corpora is influencing the excretion rate of these products. A significant correlation (0.37) was also found between the percent of total ova shed which were implanted and number of corpora lutea present, whereas the correlation (0.24) between the former and the total weights of the corpora lutea from both ovaries was not significant. This may imply that progesterone production is dependent upon the activity of the individual corpora lutea present rather than upon total mass of this tissue. On the other hand, the significant correlation (0.456) between weights of the corpora lutea and number of viable embryos would infer that the quantity of corpora lutea tissue during early gestation may be related to the number of embryos implanted and maintained.

CHANGES IN THE PITUITARY HORMONES OF SHEEP DURING THE NON-BREEDING AND BREEDING SEASONS. W. G. Kammlade, Jr., J. A. Welch, A. V. Nalbandov and H. W. Norton, *University of Illinois.*

To obtain information on the hormonal causes of the seasonal breeding behavior of sheep, the pituitary, thyroid, ovarian, and uterine changes of ewes during the non-breeding and breeding seasons were studied. The reproductive tracts and glands of 72 crossbred ewes were collected at approximately equal intervals during the non-breeding period and from 38 ewes during the estrual cycle. Eighty-seven pituitaries were assayed for gonadotropic and thyrotropic hormones and the results correlated with the reproductive stages of the ewes and their ovarian activity. The gonadotropic potency of the pituitary was found to be high and relatively constant during the non-breeding season. At the first estrual cycle the potency dropped markedly and then increased linearly from day of heat to the 15th or 16th day after heat when the potency reached the non-breeding season level. Contrary to previous assumptions, the non-breeding season is not due to a low gonadotropic potency of the pituitary but may be caused by changing proportions or secretion rates of FSH and LH. No significant trend was found in thyrotropic hormone potency of pituitaries during either reproductive stage or in the weights of thyroid and pituitary glands. Many of the follicles found in the ovaries of ewes during the non-breeding season were as large (6–8 mm.) as those present during the estrual cycle before ovulation. Two weeks prior to the onset of the breeding season ovulations without heat were frequent. Uteri during the non-breeding season showed no estrogenic stimulation.

LIPID AND LIPOPROTEIN CONSTITUENTS OF EGG YOLK IN THE RESISTANCE AND STORAGE OF BULL SPERMATOZOA. Ralph F. Kampschmidt and Dennis T. Mayer, *University of Missouri.*

Egg yolk is a complex biological mixture containing numerous substances, of which one or more are necessary for the storage of spermatozoa. Isolation of these factors seems imperative for further progress in determining the requirements of spermatozoa during low temperature storage. One of the salient features of egg yolk in the diluting medium is its ability to protect the spermatozoa from temperature shock. Results indicate that egg yolk does not alter the spermatozoa to afford this protection. The lipid portion of a lipid-protein complex of egg yolk, will protect the spermatozoa from temperature shock. Lecithin or cephalin either from egg yolk or soybeans will, in the presence of an ionizable buffer, protect the spermatozoa from rapid drops in temperature. It is shown, however, that these factors which protect against rapid drops in temperature are not sufficient for the satisfactory low temperature storage of bovine spermatozoa. The lipid-protein complex from egg yolk was very effective, in the diluting medium, for protection from temperature shock and for the prolonged storage of spermatozoa at low temperatures. In a medium containing a desirable ratio of glucose and buffer this lipid-protein complex was just as satisfactory as whole egg yolk in the low temperature storage of spermatozoa. The lipoprotein must be used fresh or in an unaltered form. It was impossible, by the methods employed in this investigation, to separate the lipid and protein and then recombine them to obtain satisfactory storage of spermatozoa.

A STUDY OF MULTIPLE OVULATIONS IN SIX FAMILIES OF HOLSTEINS. H. E. Kidder, G. R. Barrett and L. E. Casida, *University of Wisconsin and U. S. Dept. of Agriculture.*

The incidence of multiple ovulations in the experimental breeding herd of Holstein cows at the Emmons Blaine, Jr., farm was found to be 13.10% while the incidence of twinning was 1.92%, a highly significant difference. The incidence of multiple ovulations was not significantly influenced by service period, family, or length of time after parturition. There was a significant seasonal variation in frequency of multiple ovulation in the first service period and the variation in the second service period approached significance, being high in May and low in September in both cases. A highly significant tendency for multiple ovulations to follow in sequence was found. Significantly higher fertility was noted when cows were bred at an estrus following which only a single corpus luteum was formed as compared to an estrus following which two or more corpora lutea were formed.

THE TIME FACTOR IN RESPONSE OF DAIRY CATTLE TO HOT CONDITIONS. Douglas H. K. Lee and R. F. Riek, *Johns Hopkins University and University of Queensland.*

When animals are subjected to heat both deteriorating and compensating reactions occur. Excess of the first over the second is the net response. The net response in a single short exposure is a convenient method for comparing atmospheric effects or animal tolerances, but indicates little of what would happen if exposure were continued or repeated. With continued exposure the compensating may approach, keep pace with, or fall behind the deteriorating reactions. In actual practice exposure is usually repetitive. Here decay of reactions during the interval is equally important with development during exposure. Three possibilities occur—(i) with optimum interval conditions deteriorating returns to zero in interval but some compensation is carried over (acclimatization); (ii) with hot

interval conditions deterioration does not return to zero and gets progressively ahead of compensation (accumulation); (iii) with cold interval conditions deterioration returns to zero but compensation is negatived during interval, so that the net response increases with repetition (occlusion). In practice both exposure and interval conditions require examination and attention should be given in the most economical fashion.

HORMONAL INDUCTION OF LACTATION IN DAIRY CATTLE. J. Meites, E. P. Reineke, W. F. Riley and C. F. Huffman, *Michigan State College.*

Combinations of progesterone and diethylstilbestrol tablets are being implanted in non-breeding heifers and cows in an endeavor to induce optimal udder growth and lactation. In a preliminary experiment, two Guernsey heifers were implanted with 4 gms. of progesterone and 2 gms. of diethylstilbestrol. The tablets were removed 104 days later, although milking was begun earlier. At the end of 306 days of lactation, part of which time Protamone was fed, the heifers produced 331 and 323 pounds of butterfat and 6622 and 6681 pounds of milk, respectively. Two Holstein cows received 3 gms. of progesterone and 100 mg. of diethylstilbestrol, followed 90 days later by an additional implant of 1.5 gms. of diethylstilbestrol. On the 120th day all tablets were removed and milking was begun. One cow reached a peak of 80 pounds of milk daily and produced 163 pounds of butterfat during her first 61 days of milking (present time). The second cow gave a maximum daily milk yield of 45 pounds and produced 96 pounds of butterfat during her first 61 days of lactation. Factors which are believed to influence experimentally-induced udder growth and lactation include (1) ratio of the two hormones (2) total amount of hormones absorbed (3) duration of implantation (4) site of implantation and (5) character of the tablets. Progesterone is believed necessary for optimal udder growth and for overcoming undesirable features of unhindered diethylstilbestrol stimulation.

DDT IN FAT FROM CATTLE SPRAYED AND CATTLE TREATED WITH CABLE TYPE BACK-RUBBERS. A. L. Moxon, Wm. M. Rogoff and O. L. Olson, *South Dakota Agricultural Experiment Station.*

Cable type back-rubbers have been in use for several years in range areas of the Great Plains to control horn flies on cattle. The device consists of two properly braced fence posts about sixteen feet apart. Suspended between the two posts is a burlap covered cable soaked, at two week intervals, with a 5% solution of DDT in oil. Entomological observations have shown highly effective control of horn flies by this method with far less expense or trouble than is occasioned by spraying. Fat samples for analysis were taken from cattle treated for a full season with these back-rubbers and from cattle sprayed three times at three week intervals with a 0.5% DDT suspension.

DDT was determined by a procedure involving the separation of the DDT from the fat with a Celite column followed by a colorimetric measurement of the DDT.

The DDT values for the fats from the sprayed animals ranged from 10 to 30 p.p.m. The DDT content of the fats from the animals treated with the cable type back-rubbers averaged less than 2.0 p.p.m. with none exceeding 4.0 p.p.m.

COMPARATIVE HEAT TOLERANCE TEST IN CATTLE AND BUFFALOES. D. N. Mullick and N. D. Kehar, *Indian Veterinary Research Institute, Izatnagar.*

Water buffaloes play an important part in milk production and in meeting draft needs in many countries. The exact position of this class of stock in relation

to other classes of live-stock has not yet been examined. In the first year six milch cows and buffaloes of Hariana and Murrah breed were selected for study for twelve months. In the second year twelve milch cows and buffaloes were studied for six summer months only. Standard methods were followed to record weekly, the pulse rate, respiration rate and body temperature. The air temperature ranged from 52 to 108° F. with an average of 76° F. and that of relative humidity from 24 to 84% with an average of 52%. The average values in the pulse rate, respiration rate, body temperature of cattle and buffaloes are 52.5 and 41.1; 25.7 and 21.2; 101.4 and 100.4° F. respectively. In each year the values of three reactions are higher in cattle than buffaloes. The respiration rate was most variable with the air temperature. The regression equations of the cows and buffaloes are Y=0.861X-41.4 and 0.605X-26.2 respectively, where Y is the respiration rate and X is the air temperature. The drawn lines showed that in the shade the buffaloes have better heat regulating mechanisms to keep them cool than cows in higher temperature.

COMPARATIVE HEAT TOLERANCE TEST IN DIFFERENT BREEDS OF CATTLE. D. N. Mullick and N. D. Kehar, *Indian Veterinary Research Institute, Izatnagar.*

The relative reaction of different breeds of cattle to subtropical climate were examined. Six cows containing Eureopean blood (¼), six cows of Indian cross and six cows of pure Indian breed were studied weekly for 12 months to test the effect of the air temperature and moisture on pulse and respiration rates and on body temperature. Standard methods were adopted. The air temperature varied from 58 to 103° F. with an average of 78° F. and that of relative humidity was from 25 to 89% with an average of 50%. Of all the physiological reactions, the respiration rates varied most conspicuously with the air temperature. The regression equations between respiration rate and air temperature are Y=0.940X-37.0, 0.757X-35.2 and 0.861X-41.4 for foreign cross, Indian cross and pure Indian respectively, where Y is the respiration rate and X is the air temperature. The regression lines show that Indian cross reacted least and foreign cross most towards variation in air temperature and also show that the animals do not utilise the heat regulating mechanisms for cooling when air temperature was below 70° F. These lines can be conveniently used as suitable indices for heat tolerance tests in animals. The coefficients of the Iberia formula are 88, 86 and 81 for Indian cross, pure Indian and foreign cross respectively. It may be concluded that foreign blood is not suitable for the tropical countries.

THE EFFECTS OF DIETHYLSTILBESTROL, TESTOSTERONE, AND PROGESTERONE ON GROWTH AND FATTENING, AND ON CERTAIN CARCASS CHARACTERISTICS OF WESTERN LAMBS. C. C. O'Mary, A. L. Pope, G. D. Wilson, R. W. Bray, and L. E. Casida, *University of Wisconsin.*

Two-hundred western lambs (100 wethers and 100 ewes) averaging 71 pounds were assigned at random to 20 lots, 10 animals per lot, with the restriction that the sexes be kept separate. The following groups were comprised of two lots of each sex: (1) Control, (2) Diethylstilbestrol (one 12 mg. pellet subcutaneously per animal), (3) Diethylstilbestrol (two pellets per animal), (4) 20 mgs. Testosterone injected intramuscularly weekly, (5) 20 mgs. Progesterone injected intramuscularly weekly. Each lamb was taken off experiment at approximately 100 pounds live weight. The following characteristics were studied: (1) rate of gain, (2) economy of gain, (3) live grade, (4) carcass grade, (5) degree of finish, (6) Dressing percentage, and (7) length of metacarpal bone. External fat, muscle and bone were measured on a one-inch sample from each carcass taken just caudal to the 10th rib. The

percent of water in the external fat was also determined. Lambs receiving one and two pellets of diethylstilbestrol were not distinguishable and in general made more rapid gains, required less feed per pound of gain, had a lower dressing percentage, a lower carcass grade, and less carcass finish than the controls. Testosterone and progesterone had no effect. Wether lambs gained faster than ewe lambs but graded lower on foot, had a lower carcass grade and carried less finish. Length of metacarpal bone was not affected by any treatment. There was significantly less external fat on those animals receiving diethylstilbestrol; muscle and bone measurements were not affected, but the percent of water in the fat was increased over the controls.

THE INFLUENCE OF STILBESTROL ON GROWTH, EFFICIENCY OF FEED UTILIZATION AND CARCASS QUALITY OF SWINE OF DIFFERENT SEXES. A. M. Pearson, H. D. Wallace, G. E. Combs, J. W. Stroud, and Marvin Koger, *University of Florida.*

In the first trial six lots of five pigs weighing approximately 35 pounds each were allotted as follows: (1) boars—control, (2) boars—stilbestrol, (3) barrows—control, (4) barrows—stilbestrol, (5) gilts—control, and (6) gilts—stilbestrol. Stilbestrol pellets were implanted subcutaneously with 25 mg. initially, 25 mg. after one month, and 50 mg. after two months. All pigs were fed the same ration and slaughtered after 107 days. The average daily gains were 1.70, 1.50, 1.46, 1.43, 1.43, and 1.40 pounds for lots 1 through 6, respectively. The greater gain of lot 1 was highly significant. Differences in feed consumption per 100 pounds gain were small. Average thickness of backfat and carcass grades were similar except for lot 2 which had less backfat and a lower carcass grade. Lots 5 and 6 dressed 77.84 and 78.67 percent, compared to values ranging from 74.49 to 75.26 for the other lots. Palatability scores indicated the roasts from the boars were less desirable than those from gilts or barrows, with no apparent difference between treated and untreated animals. In the second trial pigs averaging 84 pounds were divided into three lots of four barrows and four gilts per lot and were treated as follows: (1) control. (2) 50 mg. of stilbestrol initially, and (3) 50 mg. of stilbestrol every three weeks. Average daily gains after five weeks were 1.26, 1.25, and 1.40 pounds for lots 1, 2, and 3, respectively.

SOME FEEDING AND MANAGEMENT FACTORS AFFECTING AGE AT PUBERTY IN CHESTER WHITE AND POLAND CHINA GILTS. G. L. Robertson, L. E. Casida, R. H. Grummer and A. B. Chapman, *University of Wisconsin.*

An experiment of factorial design was used to study the effects of three variations of feeding and management factors upon age at puberty in 48 Chester White and 48 Poland China gilts. The average age at puberty of gilts in this study was 201 days with a standard deviation of 13.2 days. Full-fed gilts tended to reach puberty earlier than limited-fed gilts, and gilts which received the low-protein ration were 6 days younger at first heat than those which received the high-protein ration ($P<0.05$). There was not an over-all significant difference in age at puberty between the two breeds, but the Chester Whites were 11 days older than the Poland Chinas in the pasture lots ($P<0.01$) and one day younger in the dry-lots. Poland China gilts were 9 days younger at puberty on pasture than in dry-lot ($P<0.05$) while the Chester White gilts were 3 days older on pasture than in dry-lot. Gilts which were born later in the farrowing season tended to reach puberty at a younger age.

THE INTERRELATIONSHIPS OF WEIGHT OF CLEAN WOOL TO FIBER LENGTH, FIBER THICKNESS, AND DENSITY OF FIBERS PER UNIT AREA. S. B. Slen and F. Whiting, *Experimental Station, Lethbridge, Alberta, Canada.*

Bimonthly wool samples were obtained from 76 mature range ewes fed various levels of protein in dry lot to study the relationships of weight of clean wool (1) to fiber length (2), fiber thickness (3), and density of fibers on the skin (4). These samples were obtained during the period of June 1949 to June 1950 from a 4 sq. cm. area tattooed on the right shoulder of each ewe. The partial correlation coefficients, $r_{12.34}=.596$; $r_{13.24}=.747$; $r_{14.23}=.758$ ($N=479$), indicated that length, thickness, and density of fibers were highly associated with the weight of clean wool produced from a measured area. The coefficient of multiple correlation ($R_{1.234}=.899$) confirmed these results. From these data it is evident that approximately 80% of the variability in weight of clean wool was the result of differences in these fiber attributes. The net regression coefficients also were found to be highly significant, $b_{12.34}=7.589$, $b_{13.24}=9.629$, $b_{14.23}=5.247$. Further tests of significance on these coefficients showed that fiber thickness had the greatest effect on weight of clean wool followed by fiber length and density of fibers on the skin. From these relationships the following regression equation was calculated: $X_1=7.589X_2+9.629X_3+5.247X_4-347.309$. From this equation it is possible to predict clean wool production from the fiber attributes studied. (Highly significant $P\leqq.01$).

SOME EFFECTS ON REPRODUCTIVE FUNCTIONS OF DIETHYLSTILBESTROL ADMINISTERED ORALLY TO GILTS. J. W. Stevenson and N. R. Ellis, *U. S. Dept. of Agriculture.*

Studies were conducted to determine the effects on reproductive processes of feeding diethylstilbestrol to gilts. Gilts which received, respectively, 0.025 and 0.25 mg. daily did not show definite differences from those receiving no stilbestrol. Ten of 12 gilts which ingested 2.5 to 250.0 mg. daily had complete cessation of estrus either immediately or following one estrous period. In one gilt at the 2.5 mg. level there was complete cessation after three apparently normal periods. The twelfth, which received 25.0 mg. daily, came into continuous estrus.

The animals in which estrus was inhibited showed teat and udder development comparable to that in early stages of gestation. With one exception, post mortem examinations of these gilts revealed uterine growth which paralleled the mammary development and which was generally proportional to the amount of stilbestrol ingested.

After stilbestrol feeding was discontinued, a control gilt and 4 gilts fed daily 0.025, 0.25, 2.5, and 25.0 mg., respectively, of stilbestrol, conceived. The control gilt and those on the two lowest levels farrowed 2, 7, and 5 pigs, respectively. The gilt receiving 2.5 mg. was slaughtered on the 59th day of pregnancy and found to contain 12 fetuses. The gilt on the 25.0 mg. level farrowed 9 pigs.

THE EFFECTS OF CONTINUOUS LIGHT OR DARKNESS ON THYROID AND REPRODUCTIVE FUNCTION IN EWES. W. A. Terry and J. Meites, *Michigan State College.*

Three groups of 5 Rambouillet and 3 Shropshire ewes were placed in 3 pens under constant light, constant darkness or under the normal light conditions prevailing between June 22 and Aug. 29, 1950. Three rams were individually rotated from pen to pen every two days. Thyroid activity was measured at the end of the

experiment by injecting each ewe with a uniform dose of radioactive iodine (I^{131}) and making direct counts over the neck at 4 to 192 hour intervals. It was found that thyroid activity was generally decreased under constant light and increased under constant darkness. The following breeding results were obtained: lambing dates were not advanced for any of the ewes in the control pen under normal light conditions; one ewe lambed earlier in the pen under constant darkness; and 4 ewes lambed earlier in the pen under constant light. The latter included the 3 Shropshire ewes. Although ewes normally become sexually active under conditions of decreasing light, it appears possible that continuous light may also stimulate reproductive functions.

MILK AND MILK-PRODUCTS AS DILUTERS FOR BOVINE SEMEN. D. L. Thacker and J. O. Almquist, *The Pennsylvania State College.*

The boiling of pasteurized, homogenized milk and pasteurized skimmilk was found to bring about changes in these products which suggest their possible use as diluting fluids for bull semen. Spermatozoa remained motile in the boiled products for periods approximately equal to those for spermatozoa in the egg yolk-citrate control. However, motility was maintained only for 1 to 3 days in the unboiled milks. Boiling of milk and skimmilk for 10 minutes appears to be adequate although no marked differences in sperm livability were obtained between intervals of 1, 5, 10 and 30 minutes or between the boiled milks and yolk-citrate diluter. Difficulty in making motility estimations is encountered with whole milk but not with skimmilk. Using the split-sample technique, a preliminary field trial was conducted at two artificial breeding cooperatives to compare pasteurized, homogenized milk boiled for 10 minutes with yolk-citrate diluter (1:1) containing 1,000 units per ml. each of penicillin and streptomycin. During April and May 48 ejaculates from 12 Holstein bulls were used to inseminate 2,197 first service cows. Based on 30- to 60-day non-returns, semen diluted in boiled milk gave a conception rate of 79% as compared to 72% for the control semen. Available 60- to 90-day non-return data (April only) for 1,351 services show 68% for boiled milk and 63% for yolk-citrate. Definite conclusions can not be based on these limited data.

REPRODUCTIVE PERFORMANCE OF BEEF CATTLE AS AFFECTED BY WINTER FEEDING. O. O. Thomas, D. F. Stephens, R. W. MacVicar, O. B. Ross, and L. S. Pope, *Oklahoma Agricultural Experiment Station.*

Presented are initial data in the study of the lifetime reproductive performance of beef cows as influenced by level of winter feeding and age at first calving. In 1948, 120 Hereford heifers were placed on this experiment. They were pastured year-long on "tall" native grass and wintered at a low, medium or high level of nutrition. The winter feeding consisted of 1 lb. of cottonseed cake per head per day for the low level; 2 lbs. of cottonseed cake the first year and 2.5 pounds thereafter for the medium level; and cottonseed cake as in the medium level plus 3 lbs. of oats for the high level. One group of heifers on each level of wintering was bred to calve as two-year-olds, the other group bred to calve as three-year-olds. More calving difficulties were encountered in those calving as two-year-olds than in those calving as three-year olds. The first calf crop was 83 and 92 percent, respectively, for the two groups. Heifers calving for the second time as three-year-olds produced as many calves as did those calving for the first time at this age. To date, there has been no appreciable difference in birth or weaning weights of calves. Seasonal variation in plasma carotene was observed; during the winter, the pregnant heifers tended to have a higher carotene and a lower plasma-phosphorus level than did open heifers. Restriction in amount of protein supplement during the winter was

reflected by a lower plasma-protein level. The red blood cell and hemoglobin values were unaffected.

THE EFFECT OF OXYTOCIN, ADRENALIN, BREEDING TECHNIQUES AND MILKING ON UTERINE MOTILITY IN THE COW. N. L. VanDemark and R. L. Hays, *University of Illinois.*

Investigations involving the use of a balloon and kymograph to record uterine motility *in vitro* have been carried out with the purpose of obtaining further evidence on the mode of spermatozoan transport in the reproductive tract of the cow. Normal activity of the uterus varied with the stage of the estrous cycle. Maximal rhythmic contractions occurred at or near the time of estrus and minimal activity occurred at mid-cycle. Tetanic uterine contractions of similar magnitude were caused at various stages of the estrous cycle by massage of the vulva, massage of the cervix, or a combination of the two. Increased uterine activity also occurred during natural mating. Uterine tone was increased during the process of milking. Intravenous injection of 15 units of pitocin resulted in tetanic uterine contractions of a pattern similar to that obtained by cervical massage. Rhythmic contractions following the tetany produced by injection of pitocin were of greater magnitude than shown prior to the injection, but gradually returned to normal. Adrenalin injections (2 ml. of a 1:1000 solution of adrenalin chloride) caused a period of quiescence and also partially inhibited the effect of pitocin at or near estrus. At mid-cycle adrenalin usually produced one contraction of the uterus but this was followed immediately by a period of quiescence.

REPRODUCTIVE PERFORMANCE IN THE RAT IN RELATION TO SELECTION FOR TIME OF PUBERTY. Edward P. Warren and Ralph Bogart, *Oregon State College.*

Laboratory rats were selected for early and late age at the time of vaginal opening for a period of three generations. Records of performance for a total of 390 first, second and third generation females were obtained. These included age and weight at the time of vaginal opening, number of young born and raised per litter, average daily gain from weaning to the time of vaginal opening and weight at 75 days of age. The two lines differed with respect to age and weight at the time of vaginal opening, average number of young born per litter and average weaning weight. The two lines did not differ with respect to number of young raised per litter, daily gain or weight at 75 days of age. Age at the time of vaginal opening was negatively correlated with weaning weight and with daily gain from weaning to the time of vaginal opening and positively correlated with weight at the time of vaginal opening. The multiple correlation coefficient (R), with age at the time of vaginal opening as the dependent variate, was 0.89. Rate of gain of females from weaning to the time of vaginal opening was positively correlated with the number of young born per litter and with weight at the time of vaginal opening and was negatively correlated with weaning weight and with age at the time of vaginal opening. The multiple correlation coefficient (R), with daily gain as the dependent variate, was 0.81.

EFFECTS OF STILBESTROL AND TESTOSTERONE PELLETS IMPLANTED INTO GROWING-FATTENING PIGS. H. L. Woehling, George D. Wilson, R. H. Grummer, R. W. Bray and L. E. Casida, *University of Wisconsin.*

The effects of implanting pellets of stilbestrol and testosterone subcutaneously were studied with 42 growing-fattening pigs. Two lots of seven pigs each were

assigned to each experimental group—control, testosterone implanted, and stilbestrol implanted. The implantations were made at the beginning of the experiment and 12 weeks later. The pigs averaged 43 pounds at the start of the experiment and were slaughtered as they reached 210 pounds. The following characteristics were studied; average daily gain, feed per 100 pounds gain, daily feed consumption, dressing percentage, length of carcass, weight of regular ham, percent of external fat in the regular ham, eye muscle measurement, fat back thickness, length of femur, specific gravity of the femur, weight of leaf fat, and seediness of the fresh belly. Of these characteristics, seediness of the belly in the stilbestrol group is the only one that showed a significant difference from the control.

The reproductive organs of the treated pigs showed definite evidence of hormonal stimulation.

NEWS AND NOTES

The forty-third annual meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago, Illinois on November 23 and 24, 1951, with a dinner for the honored guest on November 25. Abstracts of all submitted papers which are to be presented at the meeting are published in this issue of the JOURNAL OF ANIMAL SCIENCE.

The nominating committee of the American Society of Animal Production composed of L. A. Weaver, W. G. Kammlade and Arthur D. Weber has prepared the following list of candidates to be presented at the next election of officers in the annual business meeting in Chicago on November 24:

For President:—
H. M. Briggs
For Vice-President:—
M. L. Baker
J. C. Miller

Chas. E. Poulton, Associate Professor of Range Management in the Departments of Animal Husbandry and Farm Crops at Oregon State College, has taken educational leave to do graduate work in plant ecology for his Ph.D. at the State College of Washington.

D. W. Hedrick, formerly of the University of California Agricultural Experiment Station has been appointed Assistant Professor in the Departments of Animal Husbandry and Farm Crops at Oregon State College, and will handle the teaching and research duties of C. E. Poulton during his leave.

James E. Oldfield has been appointed Assistant Professor, Department of Animal Husbandry (livestock feeding and nutrition), Oregon State College, effective September 1. He holds the degrees of B.S.A. and M.S.A. from the University of British Columbia and his Ph.D. from Oregon State College.

A textbook entitled "Introductory Animal Science" by W. P. Garrigus, of the University of Kentucky, was published recently by the J. B. Lippincott Company of Chicago, Philadelphia and New York. This book is intended primarily as a text for the basic course in animal husbandry or animal industry, and also as a reference book for high school work in livestock production and for livestock producers who seek information on market classes and grades, livestock judging and breed history. The book contains introductory chapters on the livestock industry, the evaluation of livestock and the marketing of livestock and livestock products, and five parts devoted to beef cattle, sheep, swine, horses and mules, and dairy and dual-purpose cattle, respectively.

W. P. Lehrer, Jr. of the animal husbandry department at the University of Idaho received the degree of Doctor of Philosophy from the State College of Washington in June, 1951.

A third major agricultural experiment station has recently been established in the state of Georgia being located on the campus at the University in Athens and making possible for the first time in many years the routine joint staffing of personnel between the College of Agriculture and the Agricultural Experiment Station.

James L. Carmon, who holds degrees from the University of Georgia and the University of Maryland, recently joined the Animal Husbandry teaching staff at the University of Georgia.

I. A. Dyer, who recently completed the requirements for his Ph.D. degree at the University of Illinois, is now a member of the animal husbandry staff of the

College of Agriculture and the Agricultural Experiment Station at the University of Georgia.

E. P. Warren, who has been on leave of absence from the University of Georgia for the past two years while taking advanced work toward his Ph.D. degree in animal breeding at Oregon State College, has completed the requirements for this degree and has returned to the former Institution on a combination teaching and research assignment.

The 1951 revised edition of "Introductory Animal Husbandry" by Arthur L. Anderson has been published by The Macmillan Company, New York. The book is mainly a survey of animal husbandry and marketing livestock and livestock products. An attempt has been made to bring the subject matter up-to-date by including material that has become available since the previous edition in 1943. The content is organized primarily to meet the needs of beginning college students

"Principles of Milk Production" by W. B. Nevens, was published by McGraw-Hill Book Co., Inc., New York in August, 1951. This is a new book intended as an introductory text for college students beginning a study of dairy production. It should also serve as a reference book for secondary schools and for dairy farmers. It deals primarily with the principles governing economical production of milk and includes recent advances in management, housing, nutrition and breeding.

"Ecological Animal Geography" by Hesse has been revised by W. C. Allee and K. P. Schmidt and published by John Wiley and Sons, Inc., New York in August, 1951. It deals with the general problem of what determines an animal's ability to live in one environment rather than another; it also serves as a background for modern interest in conservation on a world-wide scale.

J. E. Briggs, formerly of the animal nutrition staff, Purdue University, resigned November 1 to take charge of the nutrition research and education program of the Superior Feed Mills, Oklahoma City, Oklahoma.

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